WOOD

American Cupola Practice

Mechanical Engineering

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AMERICAN CUPOLA PRACTICE

BY

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

LEWIS HUNGERFORD WOOD

ENTITLED AMERICAN CUPOLA PRACTICE

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Mechanical Engineering

L. P. Breckenridge

HEAD OF DEPARTMENT OF Mechanical Engineering

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INTRODUCTION

In taking up this subject, American Cuppla Practice, for my thesis work at the University of Illinois, I am working in connection with two other men one of whom is writing on Chemical and Physical Tests of Cast Iron and the other on Foundry Appliances. In this way it is hoped that the three papers will cover foundry work as it is today.

GROUND COVERED by WORK

In my own part of the work I have taken up the cupola itself, not in a very extensive way, it is true, but still I have endeavored to bring out the points to be noted. The first part is a short history of iron and the methods of making it in very early times. Then I have traced it down until the cupola was introduced for secondary melting before casting. Here I have gone to the cupola itself and after a short description of the old types and the English cupolas have taken up the modern American cupola as it is manufactured today. The next part deals with the practical running of a cupola and I have tried to show how it should be done under the best conditions. As a final chapter I have given a short description of our own foundry and the methods we have used in trying to obtain the temperature of molten iron.

SOURCES of INFORMATION

In looking up my authorities on this subject I found

a book, "The Cupola Furnace" by Edward Kirk, that goes deeply into the details of cupola construction and management. From this book and the "Foundry" I have obtained most of the material for my chapters on the running of a cupola, the old American cupola and the English cupola. The chapter on the Modern American cupola is taken directly from the catalogues of the different manufacturers, and the chapter on the historical side is from the encylopedias and from "Iron in All Ages" by a Mr. Swank.

OTHER REFERENCES

Keep's	Cast Iron
West's	Metallurgy of Cast Iron

AMERICAN CUPOLA PRACTICE

Chapter I

The Early History of Iron

When authentic history begins, about 776 B.C., iron and its uses were well known to the civilized world so that no definite date can be set as the time when iron was first discovered and used. It seems to be an established fact that it was known to about all peoples, to some extent, in very early times but was only made use of largely in the more advanced countries around the eastern end of the Mediteranian Sea and in China. The people of India were also well acquainted with iron and its use as we know from a large wrought iron pillar near Delhi* and from heavy iron beams found in some of their early temples; but other than this we have very little knowledge about the art as possessed by them.

CHINA.

Of the early use of iron in China there can be no doubt but the records of it are very scarce. In one Chinese record, said to have been written at least 2000 years B.C., iron is mentioned, and in others, also very ancient, both iron and steel are mentioned. Of their use of the metal at a later date Pliny the Elder, writing in the first century after Christ, says," Howbeit, as many kinds of iron as there be, none shall match in goodness the

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* From "Iron in All Ages" by Swank

steel that cometh from the Seres, for this commodity also, as hard ware as it is, they send and sell with their soft silks and fine furs," This shows us that even as late as the beginning of the Christian era the Chinese were the most advanced in the manufacture of iron.

EGYPT.

The date of the discovery of iron is given by Moses as about 2000 years before his time. Iron and instruments of iron and steel are mentioned in many places in the Old Testament showing that both Hebrews and Egyptians possessed the art in early times. The chief records of the use of iron by the Egyptians are to be found in their sculpture and painting where many implements are represented, the color given to some of which has lead antiquarians to believe that they were made of iron or steel. Many articles of iron have been found in the ruins of old Egyptian cities and in the Pyramids but most of these do not date nearly as early as the sculpture.

ASSYRIA.

There are many instruments of warfare and peace to be found in the old cities of Assyria and other Eastern countries but as we have no definite records of these they are not of much value except that they show that both iron and steel were known and used in those countries.

GREECE.

According to the early Greek chronicles the discovery of iron is attributed to Dactyles who is said to

have found the metal on Mount Ida after a very extensive forest fire; however it is believed that the Greeks first learned of the metal through their trade with the Phoenicians and Egyptians. At any rate we know that iron was known to them as it is mentioned in their early chronicles and poems. That the metal was scarce and highly prized is shown by the fact that in old inscriptions iron is mentioned as one of the spoils of war that the victorious army was very glad to seize. Also the following extract from the speech of Achilles when offering a prize at some of the games, shows the value of iron to the Greeks:-

"Stand forth, whoever will contend for this;
And if broad fields and rich be his this mass
Will last him many years. The man who tends
His flocks, or guides his plow, need not be sent
To town for iron: he will have it here." *

SPREAD of the IRON INDUSTRY.

The Phoenicians were the great spreaders of the iron industry and seem to have carried it into all of the countries where they traded, even to the distant islands of Britain. However they did little more than to introduce the industry and it was left to the Romans to create the demand for good iron and steel in quantity thru their wars and military operations. They early learned the value of iron armor as well as spears and swords

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* From " Iron in All Ages " by Swank.

made of the metal and gradually brought the manufacture of these articles to great perfection. Where the Romans went they went by force and as a consequence the production and working of iron were introduced and given a good start every where the Romans went.

GERMANY and ENGLAND.

The metal, iron, was known in both Germany and England in Caesar's time but in neither country was much of any attention paid to it. However the Roman occupation gave the industry a great start in both these countries as good rich ore was abundant. After the withdrawal of the Romane the iron industry smoldered slowly in both countries but the people of Germany awoke first and about the eighth century the country began to be known for its iron and steel products. In England the growth was slower on account of the restrictions placed upon the industry by law, in order to save the forests of the country which were being used up in order to supply the demand for charcoal.

METEORIC IRON.

The chemical analysis of pieces of prehistoric iron show a percentage of nickel which metal is not found in any of the iron ores or natural alloys but is always present in meteoric iron. This leads to the conclusion that in very early times the people did not possess the art of obtaining the metal from its ores but were dependent upon meteors for their iron.

FIRST METHOD of REDUCING the IRON from ITS ORES,

It was not long however until men learned that by placing some of the ore in a hot fire of wood or charcoal the ore would be partly reduced and a lump of spongy iron would result full of impurities but still in such a condition that by repeatedly heating and hammering it, it could be made fairly pure and roughly shaped. In this simple method no blast of any sort was used and the iron was of a very poor quality. The next step was to use a blast which was obtained by either natural or artifical means. To obtain a natural draft a steep bank or hill top was selected and a hole dug in it at the highest point, then a channel from the face of the bluff, or the side of the hill was dug leading into the bottom of this pit and the top of the channel covered over leaving only a small opening into the pit near the bottom. The channel flared out so that the exposed end, which was always turned toward the prevailing winds, presented a large area. This arrangement brought quite a blast into the furnace if the wind was in the right direction and blowing hard, thereby increasing the quantity of ore that could be reduced and also turning out a much better quality of iron. The method of using an artificial blast was much better than this as it made the operation of the furnace independent of the weather. To build this kind of a furnace a slight hollow was made in the ground and packed hard, then a wall of stone was built up around

this and places left at the bottom so that tubes could be inserted. Some kind of a bellows was attached to these tubes so that an artificial blast was produced. The next step was to raise the whole furnace a little off the ground by building up a bed of stone and forming the hollow fireplace upon it; then came the idea of making the fireplace of a hollowed out iron plate lined with a thick coat of some refractory clay. This last is the immediate ancestor of our present forge, cupola and blast furnace, all the later improvements being simply in the form of the furnace, the material of which it is constructed and the apparatus for furnishing the blast.

THE FIRST CAST IRON.

Up to 1350 A.D. the iron obtained by these processes was a wrought iron of varying grades but about this time it was found that by using a little greater blast to increase the heat and by keeping this blast up for a longer time the iron would become liquid and could be run into moulds made in sand. This great discovery was made in Germany and to the Germans we are indebted for our cast iron and the great iron industry of today.

CAST IRON in ENGLAND.

It was some time before the process of making cast iron was introduced into England and even then it was used, for several years, altogether in the work of casting ordnance for the Government. However this did not last long as the Society of Friends soon started a foundry

at Coalbrookdale and since their religious principles forbade their making cannon they had to resort to the making of grates, boilers and such general utilities, thereby introducing cast iron into every day life. At this time all the smelting was done with charcoal and as this was rapidly using up the forests, laws were passed restricting the manufacture of iron to certain districts. These laws caused other fuels to be sought and it was soon found that coke or coal would do just as well as charcoal and besides the coal could be found near the ore beds.

FIRST ATTEMPT to START IRON INDUSTRY in AMERICA.

In 1619 the Virginia Company sent a party of men to Jamestown to locate an iron furnace on a small stream called Falling Creek where there were good ore beds.* Nothing much was done though until 1621 when the company sent over another party to push along the work. The furnace was nearing completion and everything was about ready to commence smelting when in 1622 all the settlers at Falling Creek were massacred and the works destroyed by the Indians. This put an effectual stop to the iron industry in Virginia and it was not tried there again for many years.

THE START in the NORTHERN COLONIES.

The first furnace to actually melt iron in the United States was set up at Lynn, Massachusetts, by English cap-

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* From " Iron in All Ages " by Swank.

italists and the first iron taken out in 1648.* From that date until 1671 the work was carried on with much vigor but about 1671 the owners began to get into trouble thru lawsuits and in 1688 the works were shut down. The first permament iron works in the United States was started about 1656 near Taunton (now Raynham) in Bristol county Massachusetts, and consisted simply of an iron forge where wrought iron was produced directly from the ore by heating and hammering. These old works have been remodeled several times and were in use up to 1880, a period of 224 years. During the first hundred years most of the iron produced in the United States was wrought iron produced directly from the ores although there were a few blast furnaces making iron kettles and other cast iron utensils but as yet no pig iron was produced.

REQUISITES to LOCATION of the EARLY IRON WORKS.

In these early days three things were always necessary to the location of a foundry,-the presence of water power, the nearness of a forest where wood could be obtained for charcoal and the nearness to an ore bed; these last two were not as important as the first but if the wood and ore had to be brought from a distance it materially lessened the profits of the business. Although pig iron is mentioned at a later date as being produced by some of the furnaces it was not until late that any attempt was made to use this pig for anything but to be

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* From " Iron in All Ages " by Swank.

converted into wrought iron or steel. When castings were made at the foundries the iron was used just as it came from the ore without being remelted as is done at present. This was done until quite recently when it was found more profitable to have larger reducing furnaces and to ship the pig iron to the place where it was needed, and by remelting to cast it into various forms.

Chapter 2

EARLY FORMS of CUPOLAS

The cupola is a furnace designed to melt iron in order that it may be run into moulds. This furnace is vertical, round or elliptical in section and, in all up-to-date cupolas, is constructed of boiler plates, riveted together and lined with fire brick or other refractory material. At the bottom is an opening, the same size and shape as the inside of the cupola, closed by one or more hinged doors, depending upon the size of the cupola, so arranged that they will swing clear when dropped. On a level with the bottom is a small opening in the shell through which the molten metal can be drawn off, while a few inches higher are two or more larger openings through which a blast, either natural or forced, is admitted to the interior of the cupola. From six to twenty feet above the bottom is a large opening, closed by a door, through which the iron and fuel are charged.

THE STATIONARY BOTTOM.

At first cupolas were constructed with stationary bottoms made by placing a heavy iron plate on a stone or brick foundation. In this style of cupola there had to be a large opening left in the front through which the refuse and ashes could be drawn with long handled rakes after a heat was over. When the fire was started the front was usually left open until everything was burn-

ing well, then a few pieces of coke were put in and a wall of moulding sand rammed in against them and finally, outside of this, an iron apron was fastened securely to the front of the cupola. With the larger cupolas of this style the front was often put in before the cupola was charged and then the sand wall rammed up hard against it from the inside when the bottom was put in. A small hole was left through the sand and apron so that the metal, when liquid, could be drawn off. After a heat the apron was removed, the sand broken out, and then commenced the work of drawing out the slag and ashes remaining in the cupola. As a good deal of cold air was admitted at the front the slag often solidified in the cupola and had to be broken down from the charging door with long iron bars or by dropping pigs of iron upon it, so that all together it was a long hard job.

INTRODUCTION of the DROP BOTTOM.

To overcome this trouble the drop bottom was introduced. It is arranged so that by knocking away a prop the bottom plate will swing back, on hinges, and let the contents of the cupola fall to the floor before they have time to cool and solidify. No one seems to know when the drop bottom was introduced but it is certain that it has been in use for all of fifty or sixty years and probably more. It is said to have been an American idea and to have been first used in the New England states. However for many years after its introduction the old style stationary bottom was still in use in a great many

foundries.

AN OLD STYLE CUPOLA.

Fig. 1 shows one of the old cupolas that, although used many years ago, still may sometimes be found in very old foundries.* A brick or stone foundation was built up to the height that the foundryman wanted the spout to be above the ground and a heavy iron plate put on. This plate supported on each corner an iron or brick column on which rested another heavy iron plate having a round hole, the size of the cupola, cut in its center. On this plate the stack was built and as it was a good deal larger than the cupola it was built of common red brick and was not usually very high. However on account of the increase in size, over that of the cupola, very few sparks were thrown out. The cupola itself was built between these two plates and was usually made of cast iron staves set on end and reaching from one plate to the other; these staves were held together by several wrought iron bands either shrunk on or else drawn tight by bolts put through their flanged ends. Sometimes instead of cast iron staves a foundryman would cast round sections and bolt them together by means of flanges but this was more expensive and did not make as good a cupola, as the castings were apt to crack through the expanding and contracting of the cupola. These cupolas were lined with fire

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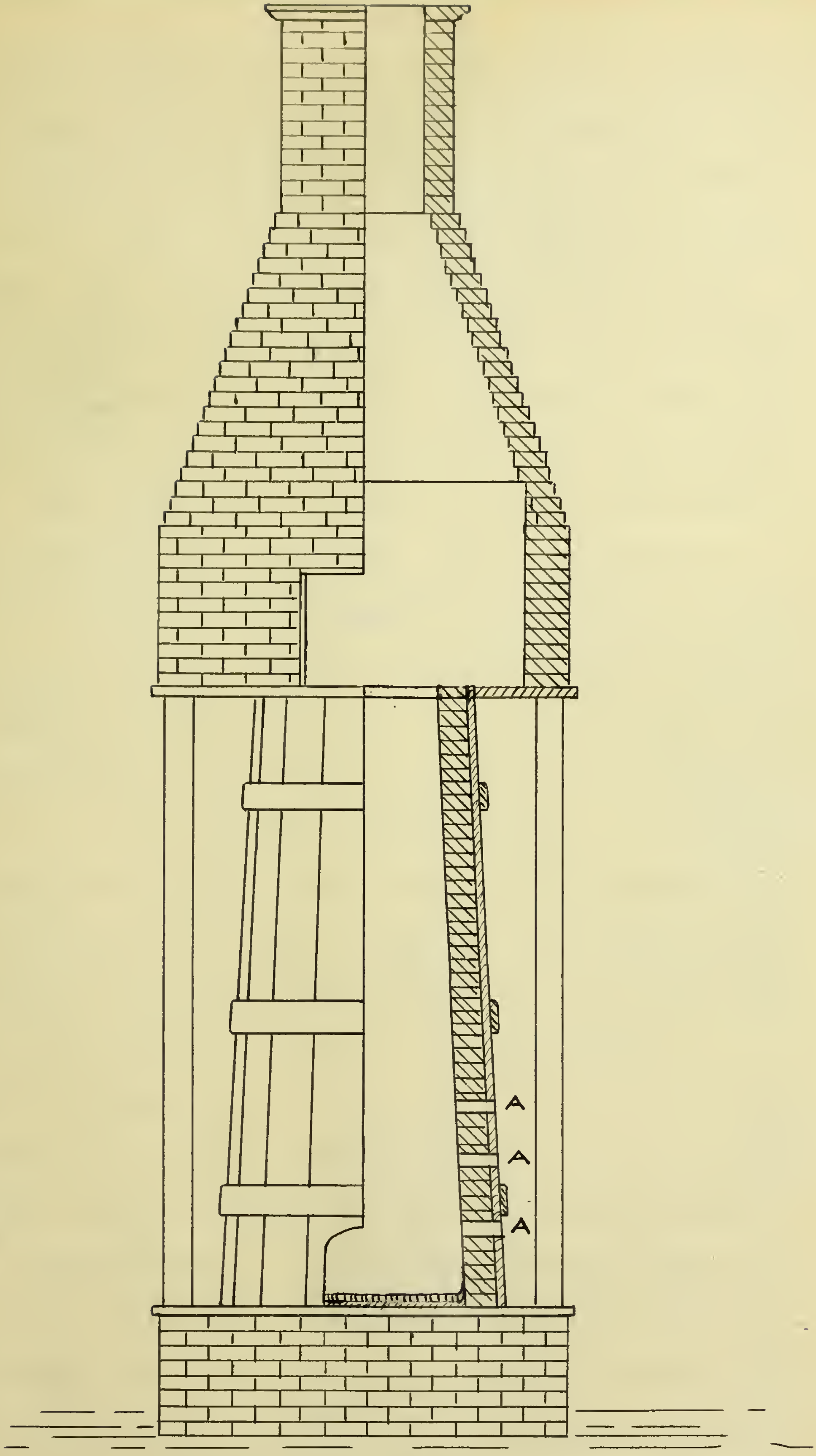
* From " The Cupola Furnace " by Kirk.



Old Style Cupola
Fig. I.

brick, or if that could not be obtained, two or three layers of common brick were put in and then daubed well with clay. There were from two to four tuyeres put on each side (A,A,A, Fig. 1). The blast was supplied through a flexible tube that could be attached to any of the tuyeres while the others could be stopped up; thus if a heavy casting was to be made the lower tuyeres were stopped and the blast sent in through the upper ones, while if only light work was to be done, the upper ones were stopped and the lower ones used. This necessitated a deep bed of fuel for heavy charges and so made the cupola very uneconomical. Most of these old cupolas were built larger at the bottom than at the top so that a large quantity of molten metal could be held in them when a heavy piece was to be cast, however, it was soon found that the stock did not settle well in a cupola of this construction but that a space was left between the stock and the lining through which most of the blast escaped, thereby making the cupola melt very slowly.

THE EXPANDING CUPOLA.

In order to overcome these objections to the tapering cupola and still to be able to hold the required metal, a cupola,* shown in Fig. 2, called the expanding cupola, was constructed. This cupola, like the other, was built on a solid base and all the refuse had to be drawn out the front. It was built of common red brick lined with fire

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* From " The Cupola Furnace " by Kirk.

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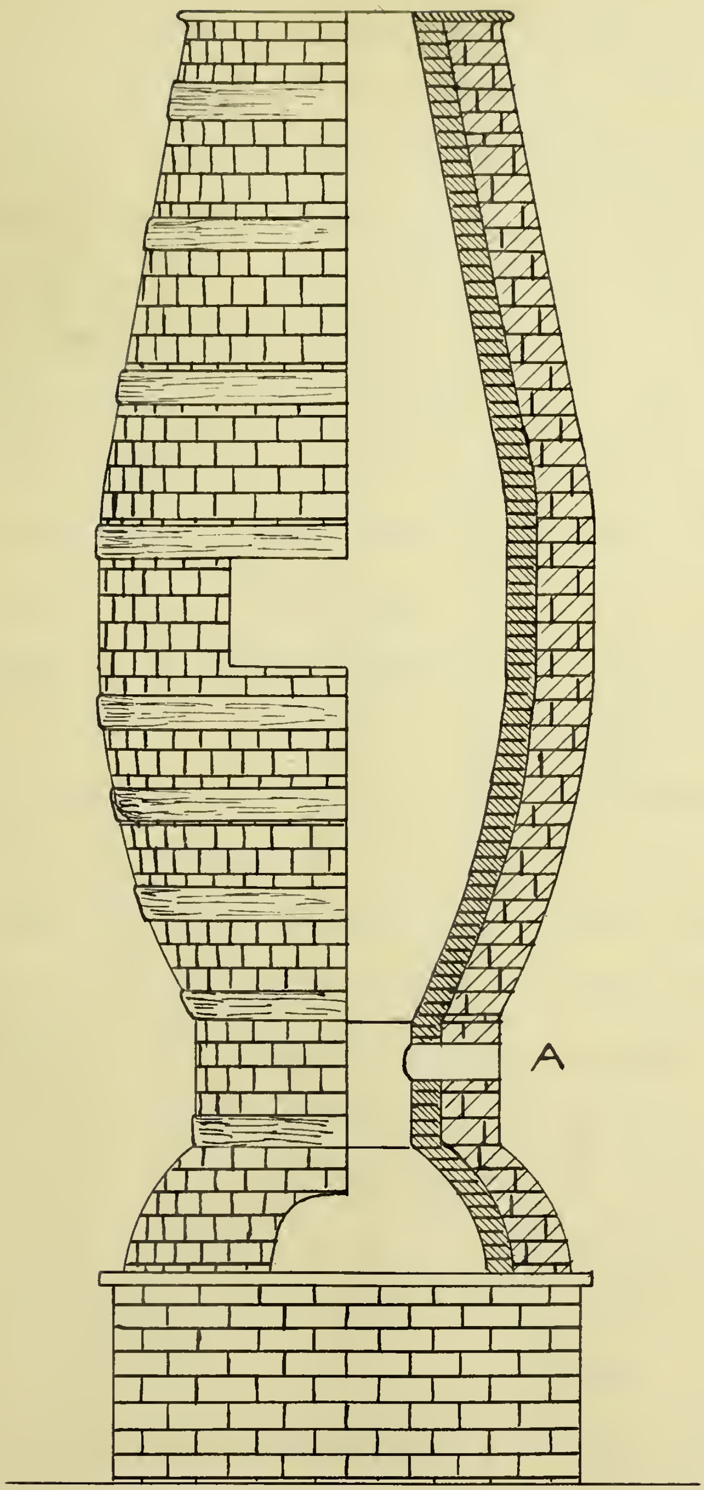


EXPANDING CUPOLA

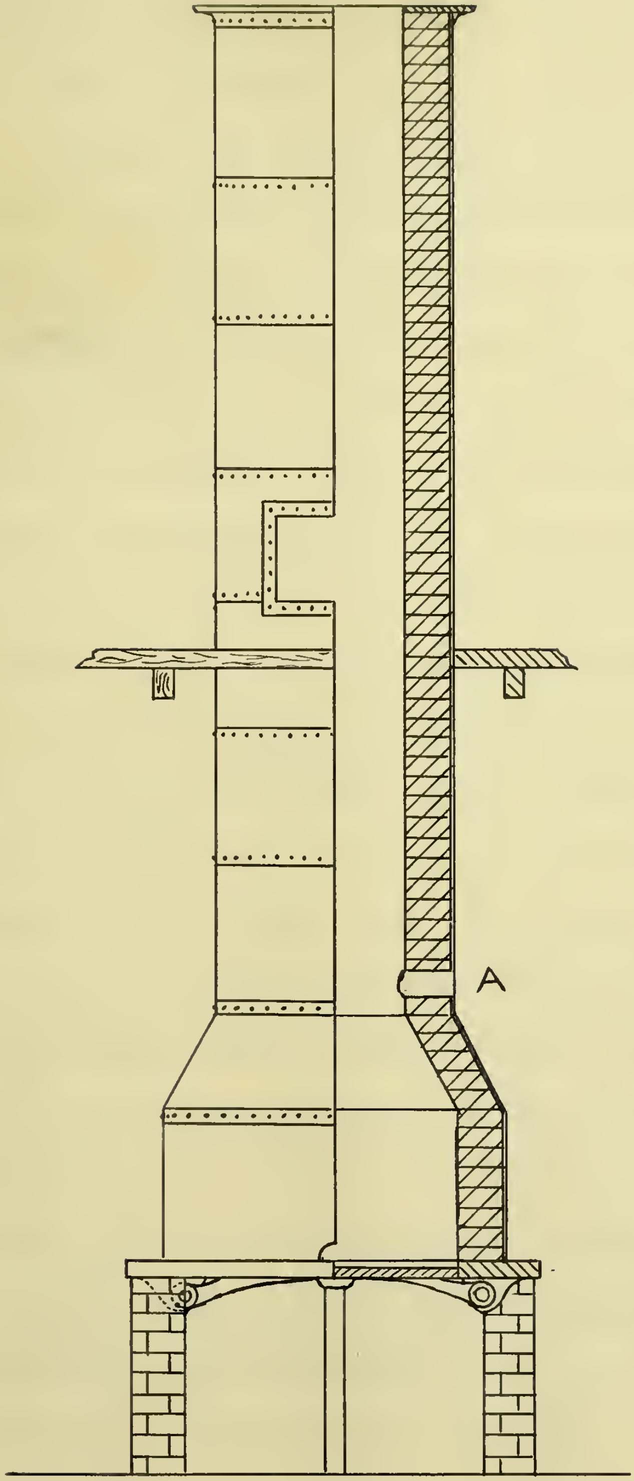
FIG. 2

brick and held solid by wrought iron bands. The cupola was contracted at the tuyeres to about one half its diameter at the charging door and then expanded again at the bottom to nearly its first diameter; from the charging door up it gradually contracted again to the top. There was only one row of tuyeres in this cupola but on account of the large diameter abo ve the tuyeres a large amount of iron and fuel could be charged at once so that the heat was better utilized than in the other cupola. These cupolas were very good in the larger sizes but with the small ones too much fuel was necessary for the bed and they were apt to bridge.

THE TUYERE AREA of THESE OLD CUPOLAS and THE MELTING.

One very serious defect in these old cupolas was in the tuyere area which was never made nearly large enough for the size of the cupola. The tuyeres were constructed small with the idea of shooting a strong blast into the center of the cupola to produce a hotter fire there, but by doing this they failed to get in enough air and so their cupolas melted slowly. The melting in cupolas of this type was very slow due partly, as stated above, to the lack of air and partly, to the fact that the charging door was only a few feet above the tuyeres thereby allowing a great part of the heat to escape up the stack.

Of these two old forms, mentioned above, the first seems to have been used the most and was in general use at the time that the drop bottom was introduced. The foundrymen seem to have taken to this slowly and it was



RESERVOIR CUPOLA with DROP BOTTOM

FIG. 3

the only improvement gotten out for a long time. However when the idea of improving the cupola came up again it was rushed and inaa very few years we had the cupola practically asiit is today.

IMPROVEMENTS, BOILER PLATE SHELL, TUYERES & WIND BOX.

Fig. 3 shows the first of these improvements which was to construct a shell of boiler plates and to continue it up thereby doing away with the old brick stack.* The lower part of this cupola was enlarged to about one third greater diameter than the rest so that a large quantity of molten metal could be held in it at one time. There was only one row of tuyeres placed just above the point where the cupola started to expand. This cupola did not prove to be much better than the others as there was still a great lack of air, and in the smaller sizes, it took so much fuel to build up the bed that the melting was very uneconomical. The next step was to make the cupola straight, to put in more tuyere area and to construct a wind box around the cupola so that the air that was furnished had no chance to leak away before it got into the interior of the cupola. Then the tuyeres were lowered to from 4 to 10 inches from the bottom, depending upon the class of work that was to be done, instead of 18 tp 20 inches as they had been before; This last improvement brought the cupola to practically the same form that it has today.

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* From " The Cupola Furnace " by Kirk.

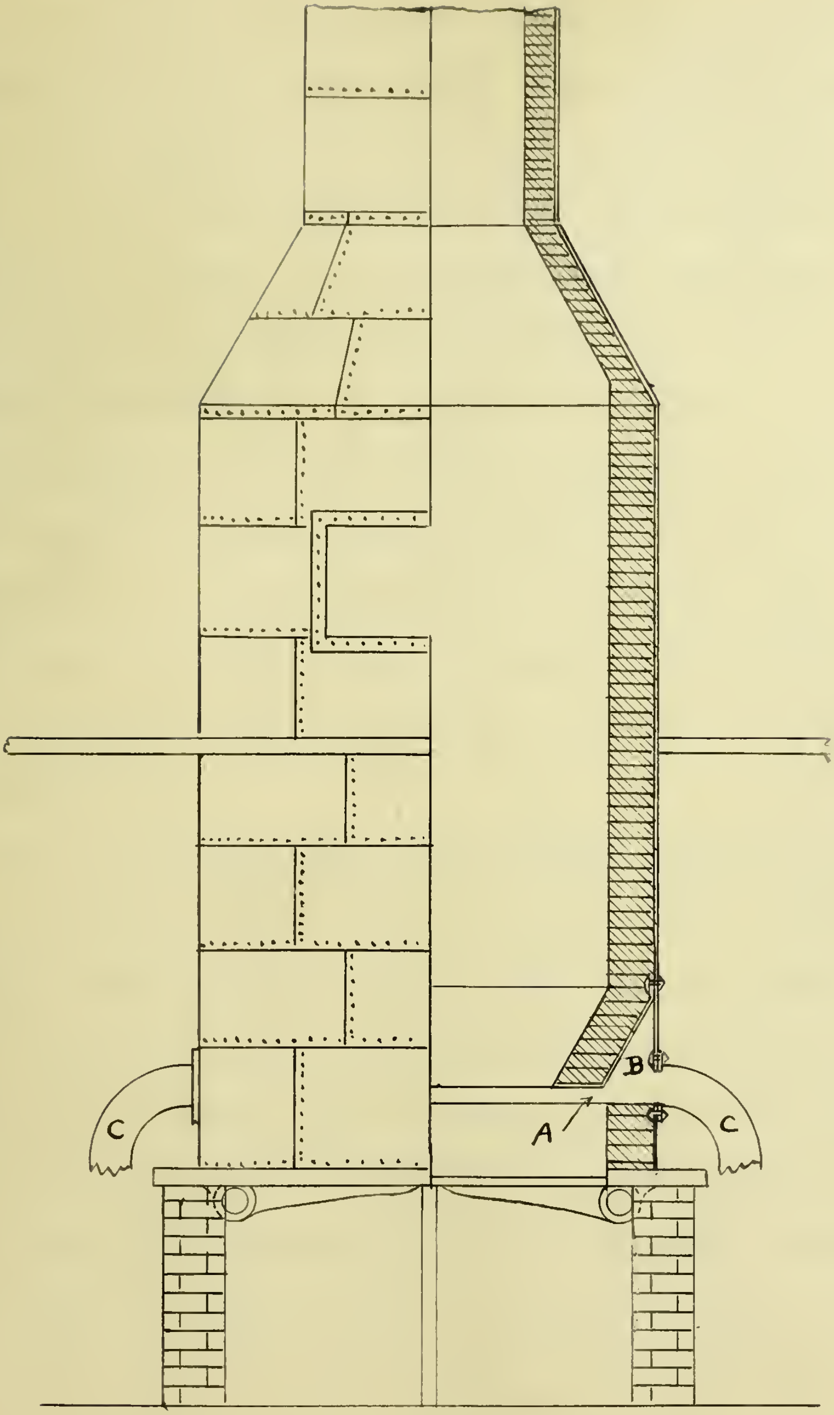

FIG. IV

MACKENZIE CUPOLA

THE MACKENZIE CUPOLA,

The Mackenzie Cupola*, so called from its designer, Mr Mackenzie, a practical moulder and founder of Newark, N.J., was the first in which the idea of a large tuyere area to admit the blast was used. This cupola is shown in Fig. 4 and was a good cupola when used in the large sizes but on account of the contraction just above the tuyeres was very apt to bridge over during a heat thereby melting very slowly if not stopping up altogether. The wind box, B, was a part of the shell, the blast being delivered to it through one or more pipes, C,C. From the wind box the air had a continuous inlet through the belt tuyere, A, which encircled the cupola.

CONCLUSION.

There have been many improvements suggested and tried with respect to the shape and size of the tuyeres and their location, the interior shape of the cupola and the introduction of steam into the blast but these seem to have been dropped about as soon as tried until now we have again the plain round cupola used forty or fifty years ago, but much modified as to height, arrangement and shape of tuyeres and other small points.

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* From " The Cupola Furnace " by Kirk.

Chapter III

English Cupolas

English cupola practice is in some respects quite different from American. The cupolas can hardly be said to be up to date as they are of an older style and the improvements that are so quickly taken up in this country seem to come in much more slowly there.

A great share of their homemade cupolas are still of the old style stationary bottom, draw front type, notwithstanding the advantages in dumping and cleaning offered by the drop bottom. Of course with the stationary bottom there is no danger of a run out or of having the doors broken or warped but with intelligent work in making up the sand bottom after the doors are closed there is scarcely any danger of losing the heat thru fault of the bottom. Another idea that is used in England to some extent is the placing of a steam jet in the stack and thereby producing an induced draft. The advocates of this method claim that it does not take any more steam than the engine for the blower would and saves all the elaborate systems of engines, blowers and piping, but, even if this is so, there is no rushing this cupola as the draft can not be forced and in order to get a cupola that can be used for long heats it necessitates quite an additional amount of original construction and takes up more floor space.

IRELAND'S CUPOLA

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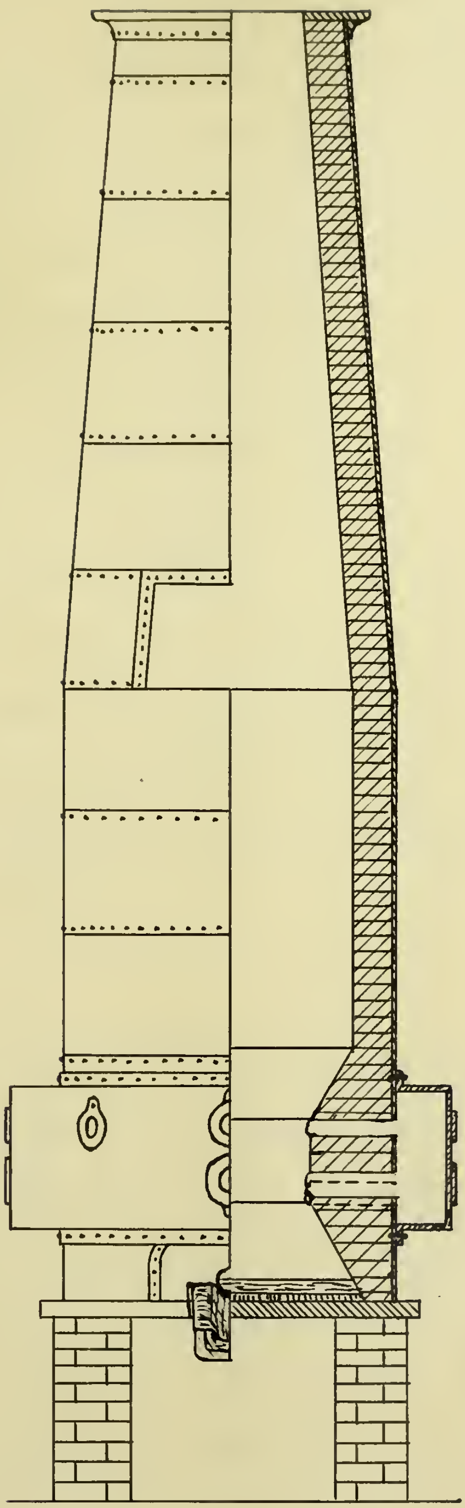

Fig V
Ireland's Cupola

In Fig. 5 is shown one type of the English stationary bottom, draw front cupola, known as Ireland's cupola from the name of the man who invented it.* The cupola has the usual boiler plate shell lined with fire brick but instead of being straight all the way up as the cupolas in this country are, it tapers above the charging door to about half the diameter below. There is a slag hole, shown at A, and usually two rows of tuyeres, shown at B B, the upper ones being smaller in size but greater in number. The blast is supplied from a wind belt riveted to the shell of the cupola and connected to some kind of a blower. The cupola is boshed or contracted at the tuyeres and then expanded again below so as to hold more metal. Most of these cupolas are built with the stationary bottom but they can easily be fitted with the drop bottom if the foundryman so desires.

STEAM JET CUPOLA

In Fig. 6 is shown the old style cupola where an induced draft is produced by a steam jet in the stack.** The shell is straight, up to the charging door where it contracts rather sharply to a small diameter; at this point the steam jet is introduced and by the velocity, which the steam obtains in going up the stack, produces a draft. At the tuyeres, of which there are usually two rows about ten inches apart, the cupola is boshed in

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* From " The Cupola Furnace " by Kirk

** From " The Cupola Furnace " by Kirk

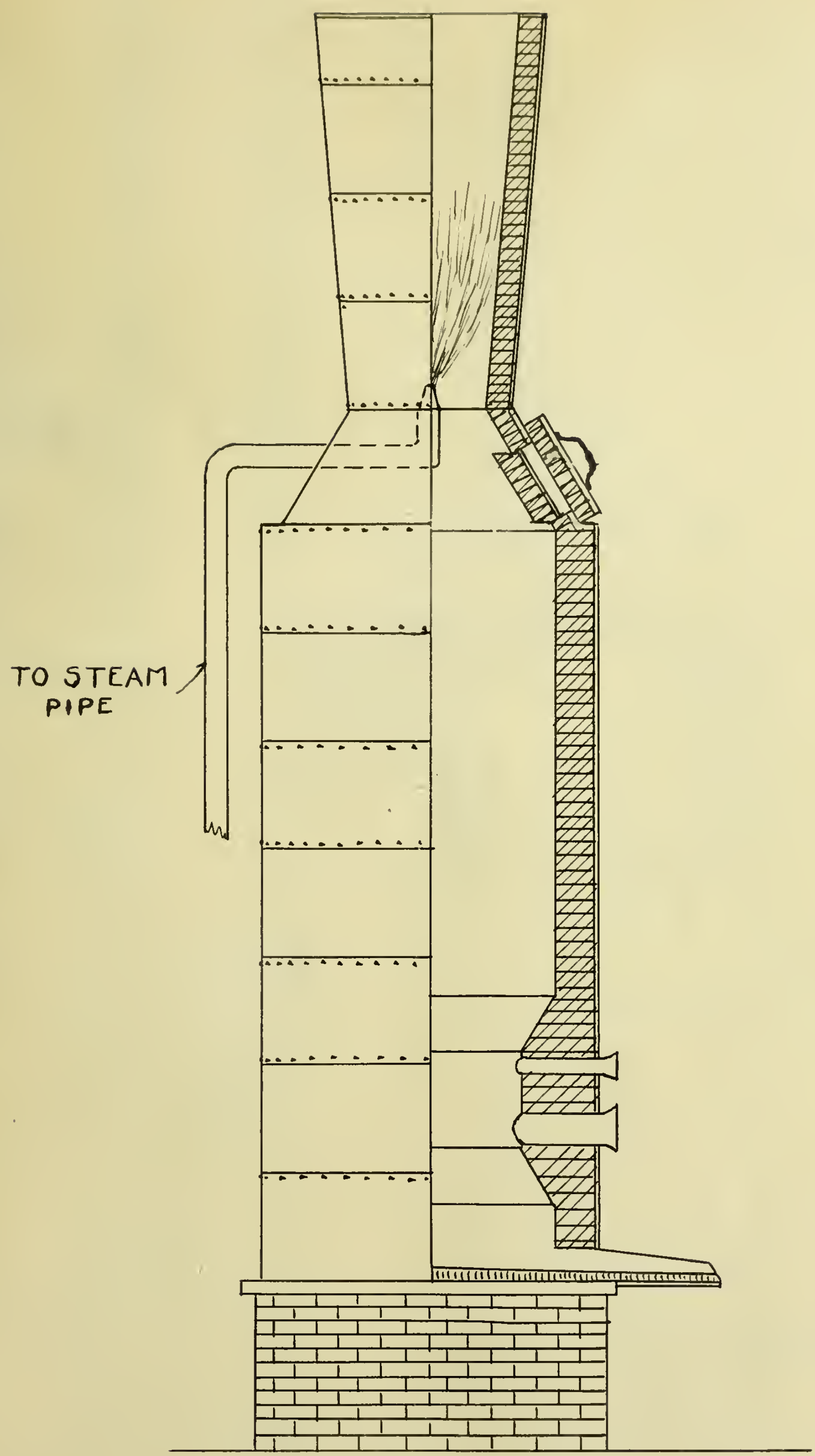

FIG. VI

STEAM JET CUPOLA

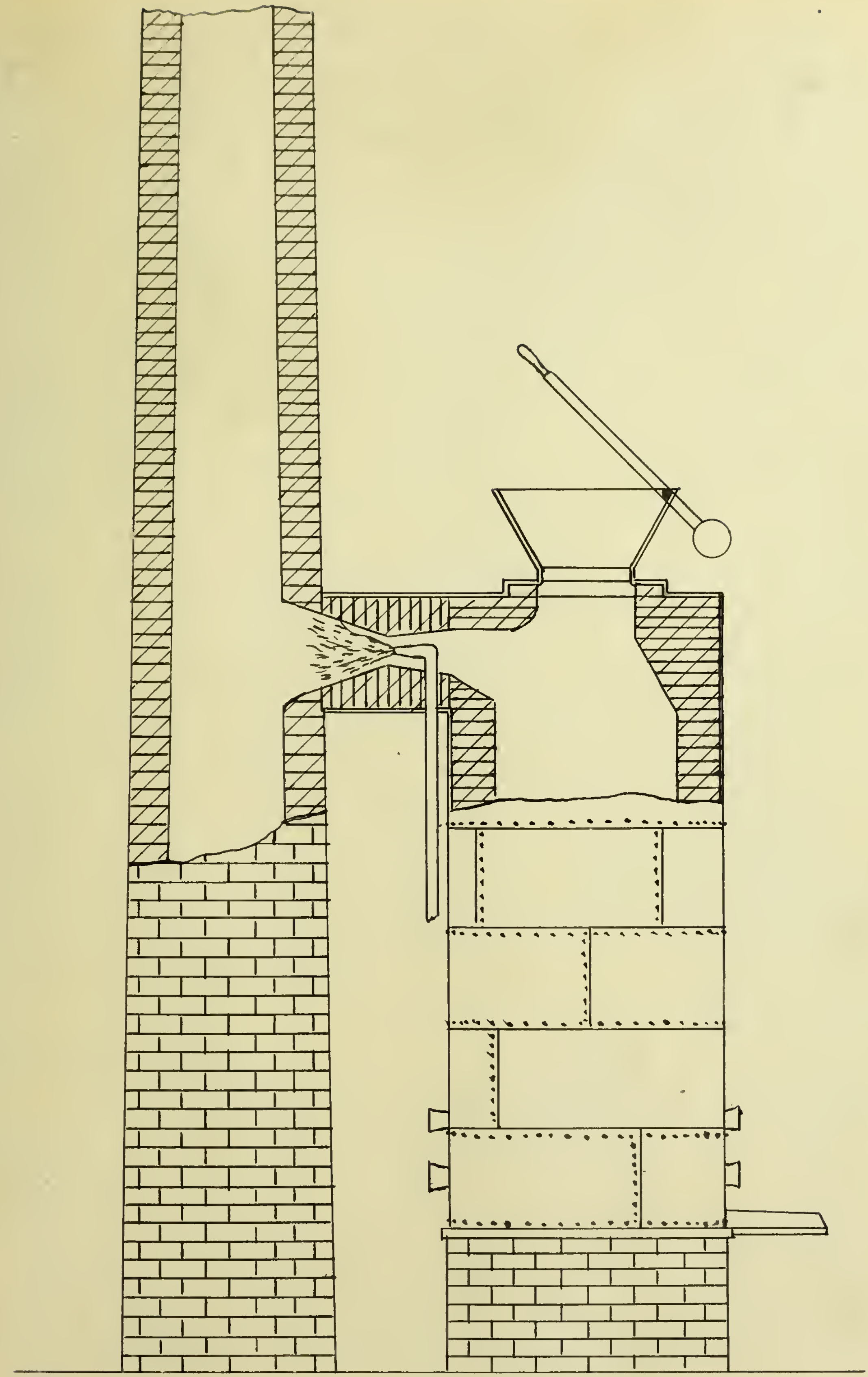

Fig. VII

Steam Jet Cupola

order to throw the blast tothe center of the fire and so get even combustion over the whole area of the cupola. These cupolas can be made, either as shown in the sketch, with a stationary bottom or with a drop bottom. The great disadvantage of this furnace lies in the fact that the whole charge must be put in before the steam is turned on as any opening of the charging door afterwards has the same effect as the stopping of the blower would have in the ordinary cupola: it stops the melting for a short time and so causes the cupola to bung up after a few additional charges have been put in. To overcome this objection the cupola shown in Fig. 7 was constructed. The steam jet is introduced at B, and the charges are placed in the hopper C; when more fuel or iron is needed in the furnace the bottom, D, of the hopper, is dropped allowing the charge to fall into the furnace while by the lever E the bottom is immediately closed before enough air has gotten in even to spoil the draft for a very short time.

THE TANK CUPOLA

Another scheme that is used a great deal in England is to place in front of the cupola a small tank into which the metal runs as soon as melted. This is shown in Fig. 8 applied to the ordinary type of drop bottom cupola, and consists simply of a boiler plate tank lined with fire brick and fitted with a tight cover. The iron runs into this as soon as it is melted in the cupola thereby allowing large castings to be made in a shop

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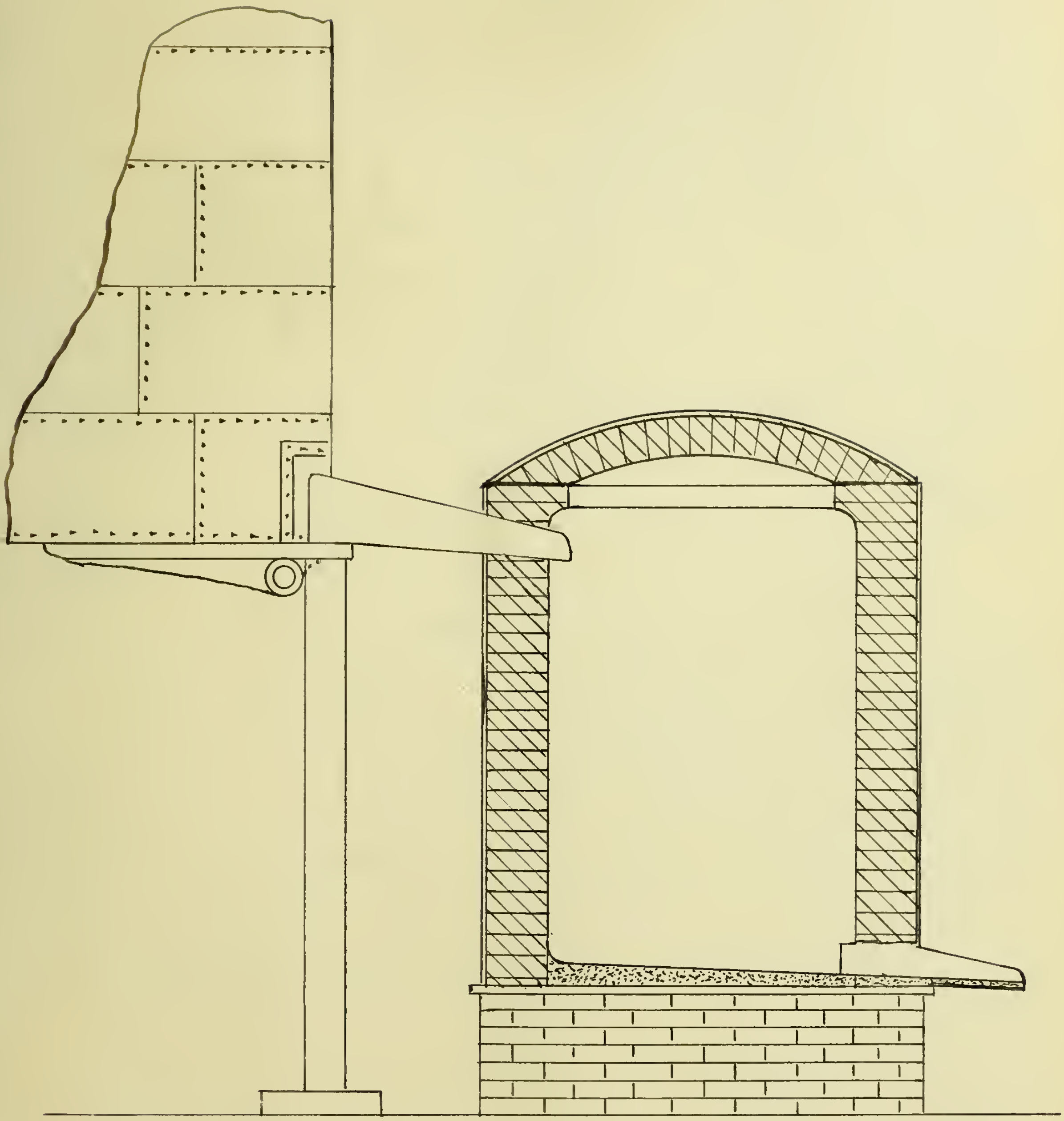

FIG. VIII

TANK CUPOLA

where there is only a small cupola, as the metal can be held in this tank until there is enough to pour the mould. The tank is fitted with a regular spout and is set upon a solid base as sometimes it has to hold quite a heavy charge of molten iron. When the fire is started the tank is filled with charcoal and the liquid metal runs into it, where it is allowed to stand for a short time in order that it may become thoroughly mixed and also that the charcoal may burn out some of the carbon, thereby softening the iron. The use of a tank has not come into American practice as it makes that much more to get ready each time and to keep in repair, and the foundrymen claim that they can make just as soft iron by running their cupolas right as by using a tank.

A great many cupolas are being imported into England at present but as the English manufacturers see that more and more foreign cupolas are being used they are waking up and beginning to make what the trade wants so that soon we shall find the English cupola practically the same as the American.

Chapter IV

Modern American Cupolas

We will now turn to the American cupola as it is manufactured today and will attempt, with the help of sketches, to give a short description of each of the leading makes.

THE COLLIAU CUPOLA

The present Colliau cupola, as manufactured by Byram & Co. of Detroit, Michigan, only differs from the original Colliau cupola in that the wind box is only high enough to enclose the tuyeres while in the first cupolas it was built way up to the charging door with the idea that in this manner a hot blast would be supplied. This did not prove to be the case so the high wind box was abandoned for the short one of today. This cupola is shown in Fig. 9. The air enters the wind box from two pipes A A, one on each side of the cupola, thereby keeping an even pressure at all points. The arrangement of the tuyeres is shown in Fig. 10, the upper half being a section through the upper tuyeres and the lower half a section through the lower tuyeres. There are six tuyeres in each row, the upper ones being elliptical in section and contracted toward the inner end while the lower ones are much larger, rectangular in section and flared at the inner end. The following is a part of what Byram & Co. have to say, in their catalogue, about the Colliau cupola;-

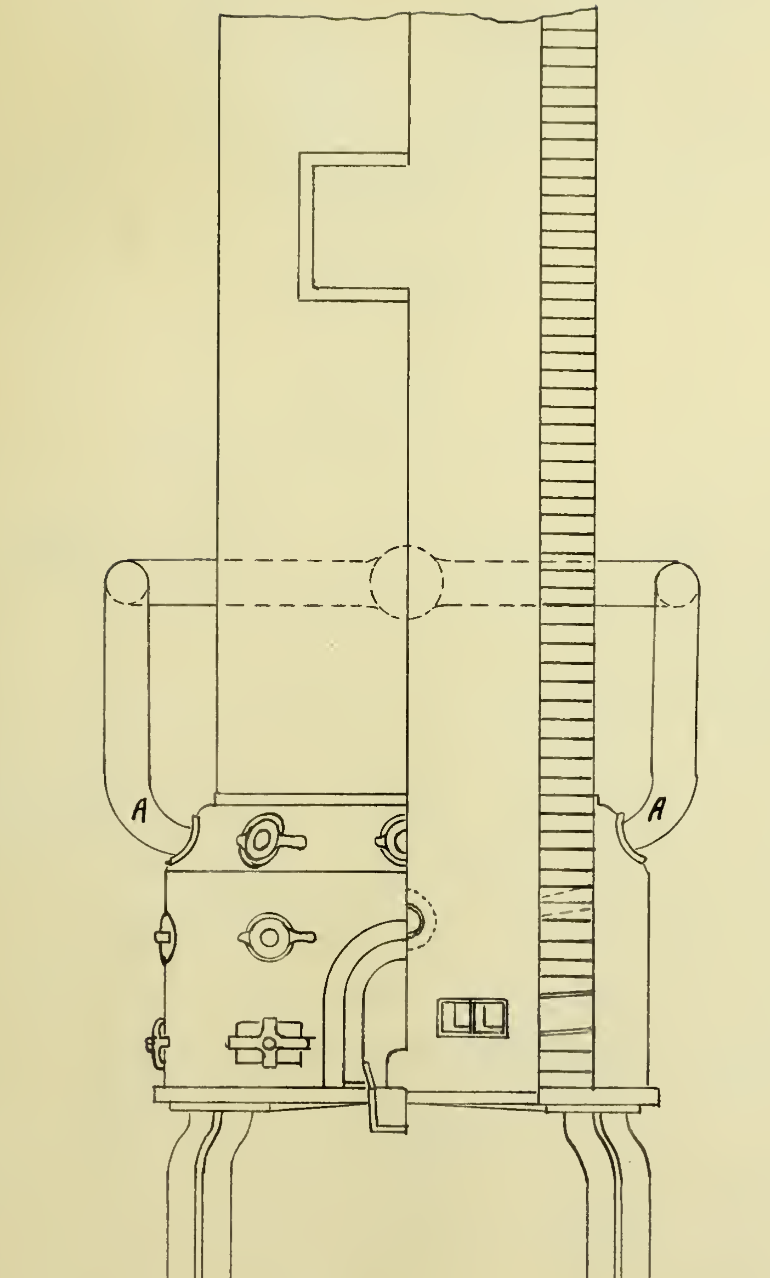

Fig. IX

Colliau Cupola

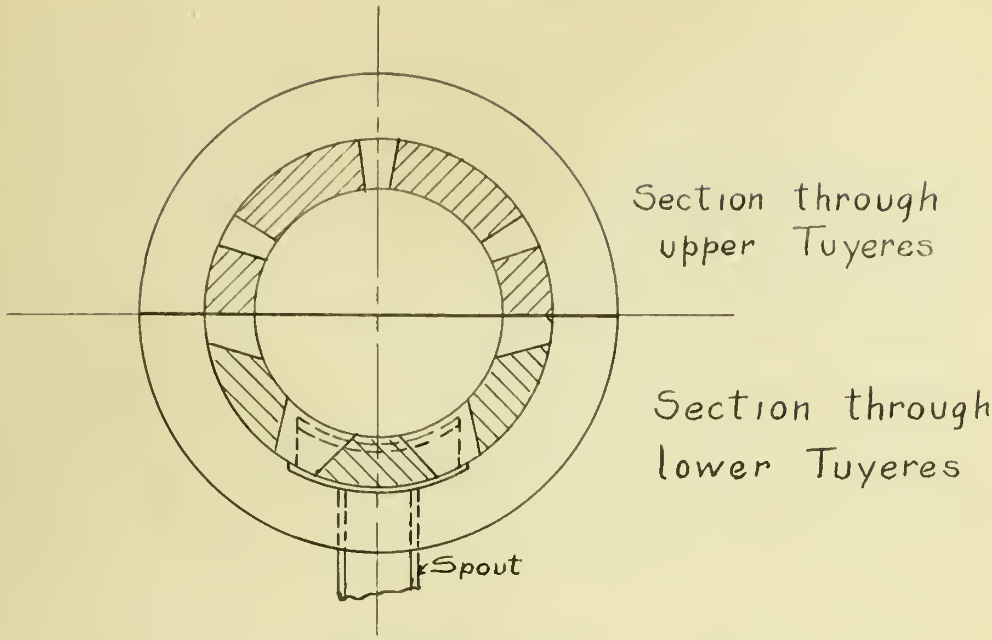

Fig X

Tuyeres of the Colliau

"The lower portion of 'The Colliau' Cupola is composed of two sheet steel shells, the inner one being made very heavy and of the same size as the stack proper, the outer shell encircles the inner one and is made air-tight, forming the air chamber, which varies in size according to the size of the furnace. In the outer shell are arranged two doors or shutters held in position by tap bolts, also made air-tight. which may be removed and again replaced after cleaning, should any coke or slag accumlate in this chamber.

"Besides this, we place a hand hole in the outer shell of the air chamber directly below each lower tuyere, held in position by a crab and bolt. Our air chamber is not fastened to the bottom plate, but is separate and distinct, and is air-tight in itself.

"Opposite each tuyere also is a sliding air-tight gate

with peep hole, and in the beveled top is furnished a brass nipple to connect hose from the blast meter into the air chamber.

"Our present tuyeres are of the latest and most approved patterns, so arranged that the blast is distributed over the entire area of the combustion chamber, and are constructed in such a form that the melted iron in its downward course cannot pass through them into the air chamber. If desired these lower tuyeres can be made adjustable in height.

"The 'bottom plate' of each furnace is made of four (4) pieces, with a joint over each leg, at which point it is reinforced by a steel plate. This arrangement permits of the necessary expansion and contraction without the possibility of cracking.

"Each furnace is provided with a metal alarm and trap with fusible disc.

"The furnace, as a whole, is simple in its construction. There is no complicated machinery or parts to get out of order, and consequently it does not require any more attention or repairs than a common cupola.

"In large shops, where a large number of hands are employed, the most important factor in melting iron is the <u>rapidity</u> with which it can be done.

"The records of 'The Colliau' in this respect have never been excelled.

"The Cupola can be operated by an unskilled workman, if instructions are followed."

THE PAXSON COLLIAU CUPOLA

Another form of cupola which is almost identically the same as the furnace manufactured by Byram & CO. is the Paxson Colliau manufactured by the J.W.Paxson Co. of Philadelphia, Pa., illustrated by Fig. 9. It has the regular boiler plate shell lined with fire brick or composition fireproof lining, single thickness above the charging door and double below where the more intense heat comes. There are angle irons riveted to the shell at intervals allowing a portion of the lining to be removed and repaired without disturbing the rest. Attached to the lower part of the shell but independent of the bottom plate is the wind box; it is made of boiler plate and carefully caulked to keep it air-tight. The blast enters in a downward direction from two pipes, one on each side of the cupola, thereby producing an even pressure at all points. There two rows of tuyeres of six each, the two rows being staggered and the upper ones being a good deal the smallest in cross-section. All are given a slight slant downward to prevent any iron from running into them and to send the blast into the center of the cupola better. In one of the lower tuyeres is cut an over-flow so if the iron rises too high, before it is drawn off, it will run out through this into a small funnel in the bottom plate and by burning out the fusible plug, with which the funnel is stopped, give warning of the condition inside the cupola. In case a small heat is to be taken off the upper tuyeres can be

closed by a rod that projects through the wind box, or if it is desired to run the melted iron from the cupola as fast as it comes down the lower tuyeres may be lowered by a very ingenious method. The tuyeres are made double and in order to lower them, all that is necessary is to take the fire brick out of the lower section and replace them in the upper. Opposite each tuyere is an opening in the wind box supplied with an air-tight cover in the middle of which is a piece of mica so as to give a chance to look into the cupola while in blast. Directly below each of the lower tuyeres is a hand hole with a tight fitting cover held on by a crab and bolt. The bottom plate is very heavy and is supported on four iron legs fastened together at the bottom by tie rods to keep them from spreading.

THE WHITING CUPOLA

We will next take up the Whiting cupola. It is illustrated by Fig. 11 which, with the following facts and description, is taken from their catalogue;-

"The leading position of the Whiting cupola is due largely to the fact that constant improvements have been made, whose value could only have been apparent to the practical foundryman. Our experience in melting iron covers a period of thirty years.

"Long experience has unquestionably proven that this cupola is the most successful and practical on the market. Economy in the use of fuel is certain. Iron produced is hot, fluid, of uniform grade, and is melted.

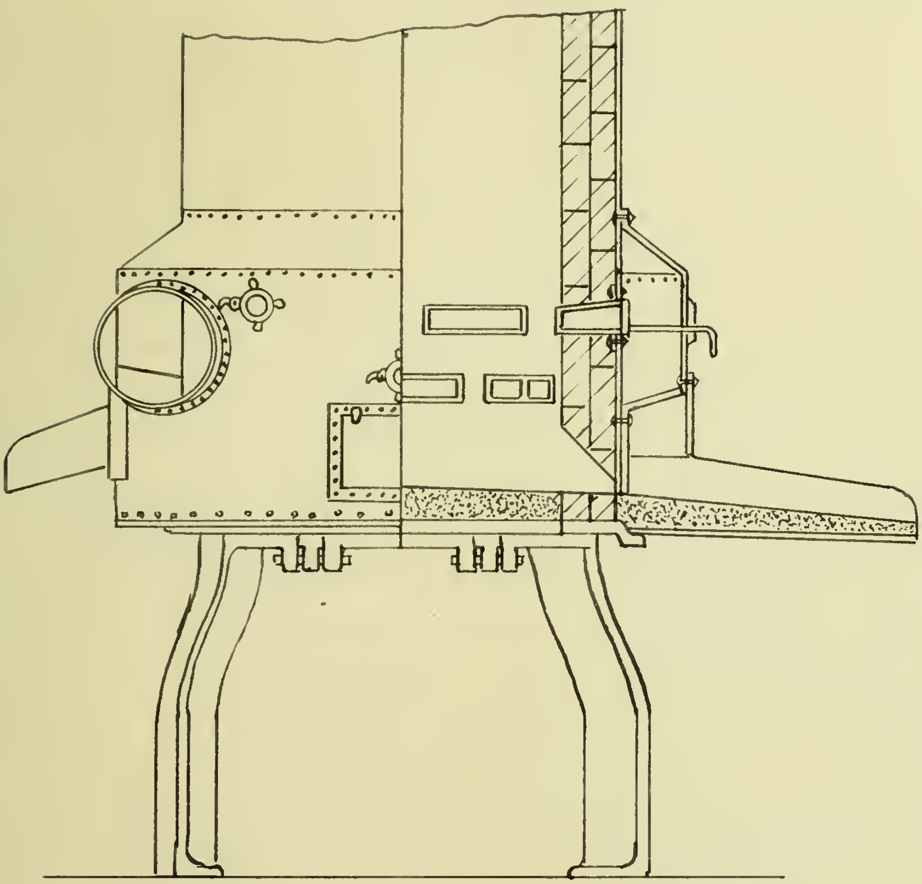

Fig. XI.

Whiting Cupola

rapidly. Bottom drops clean and the damage to the lining is reduced to a minimum.

"The 'Whiting Cupola' is the heaviest and best designed cupola in the market, and the construction is such that they are simply beyond competition with the ordinary cupolas offered to the foundryman.

"The first considerations of the design have been in the line of strength and durability. The peculiar arrangement of the blast entrance, tangential to the wind box, which has been so successful with the Whiting Cupola, also the very practical design of the cleaning door, with large opening and simple locking device, is clearly indicated. Platform plates are attached to the bottom plate through flanges in an improved manner and they are supported on substantial brackets. Foundation plate is of a new design, consisting of a combination of cast iron and structural steel, making a very rigid construction, and is now used on all sizes, No. 3 and larger,(diameter of shell 46" or more)

"The figure indicates clearly the internal construction of the body section. The universal satisfaction given by the Whiting Cupola is due largely to the patent arrangement of the tuyere system, which accomplishes the most efficient distribution of the blast yet devised.

THE PATENT TUYERE SYSTEM

"There are two rows of tuyeres with relative position as indicated. They are flaring in shape and admit the blast through a small area in the shell, which is ex-

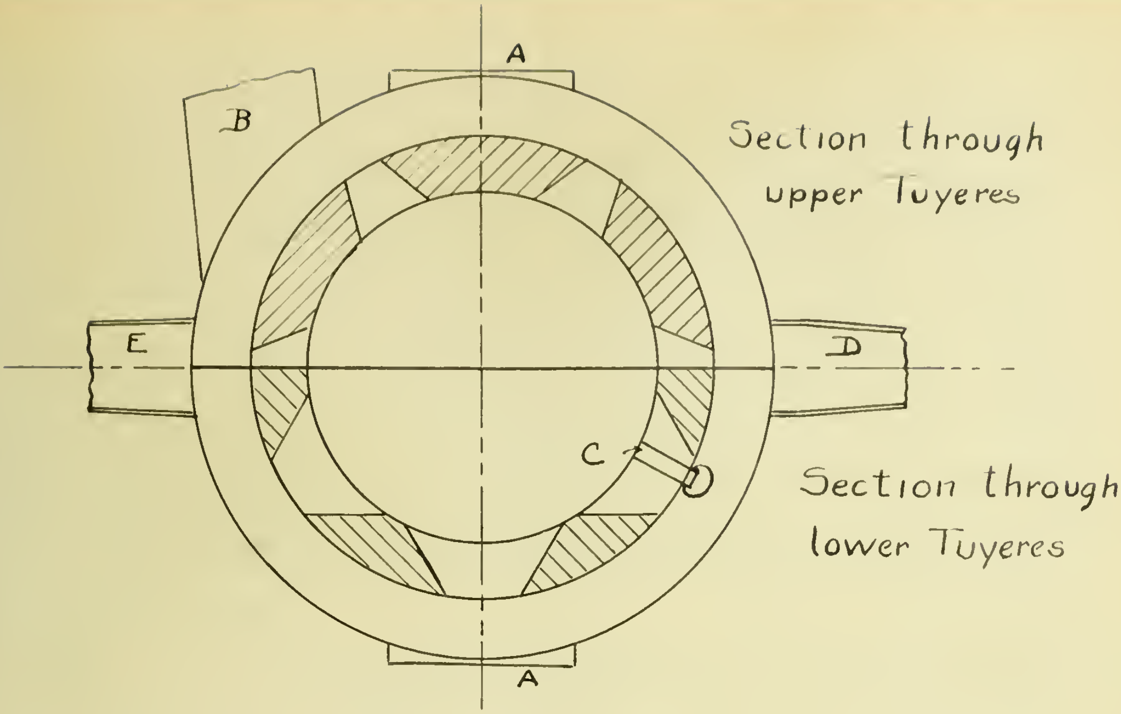

FIG. XII

Tuyere System of the Whiting Cupola

panded into a large horizontal opening inside the cupola. The air is thus permitted to reach the fuel thru an area nearly double that through which it enters the tuyeres, admitting the same volume but softening its force."

Fig. 12 is a horizontal section through the cupola, the upper half being through the upper tuyeres and the lower half through the lower tuyeres. A A are the two cleaning doors; B is the pipe leading into the wind box; C is the safety tuyere; D the spout and E the slag spout.

"The lower tuyeres form an annular inlet, distributing the blast continuously around the entire circumference of the cupola. The tuyeres can be placed at varying heights. Adjustment is secured by means of a patented device furnished only with the Whiting Cupola. Proper efficiency

may thus be maintained though the original requirements of operation be modified.

"A large cupola running on small heats will not melt with economy, unless the thickness of the lining be increased, and this arrangement affords a practical means of lowering the tuyeres to suit the lining. Also, they may be arranged for either coal or coke fuel or for output ranging from heavy machinery castings to light agriculture work.

"The upper tuyeres are of a similar construction to the lower and are intended to supply sufficient air to utilize to the fullest extent any escaping fuel gas. These tuyeres are of great service in quick melting and in large heats. For smaller heats they may be closed by our Improved Independent Tuyere Dampers. A safety tuyere is provided, having a soft metal attachment which gives warning automatically when the iron is too high in the cupola.

"Peep hole frames, machined air-tight, fitted with mica are placed opposite each tuyere: they are fitted with a hinge cover; allowing them to be opened when necessary to clean out the tuyeres.

"The blast pipe nozzle is arranged to enter the chamber on a line of a tangent, forcing the blast with a spiral or rotary motion around the shell, avoiding friction and resulting in a corresponding economy of power. This arrangement permits a large saving over other designs in cost of blast pipe.

"Cleaning doors, cast iron. Readily removable. Necessary only to turn two latch buttoms: are provided on each side of the air chamber, four on sizes No.8 and larger and two on smaller sizes. These permit convenient access to the interior of the air chamber in order that it may be properly cleaned out from time to time.

"A blast gauge of improved design, showing the air pressure at all times is provided with each cupola; this gauge may be connected with the air chamber or with the blast pipe, and situated in any convenient place readily accessible to the operator. It is furnished with rubber tubing and brass nipple for connection to the blast supply.

"Slag spout, improved design. Does not require lining. Made with curved bottom and very heavy. The latest in the market.

"Lining supports of cast iron are placed inside the stack, these being of sufficient width and strength to support the brick lining above them. One shelf is placed immediately above the air chamber, allowing that portion of the lining below to be repaired or replaced without removing the upper portion. Another shelf is placed just above the charging doors, and one shelf is provided for about every ten feet above this point.

"All joints of stack open downward on the outside. This is a feature first introduced by this company, and has the advantage of shedding water and keeping it out of the joints, preventing rust to the stack and damage

to the lining from this cause. The stiffener angle around the top is also attached in such a manner as to prevent rain working in between the shell and the lining."

THE NEWTEN CUPOLA

The other leading American cupola is the Newten, manufactured by the Northern Engineering Works of Detroit Mich. and illustrated in Fig. 13. The following description is taken from the catalogue of the manufacturer,-

"The bottom plate is very thick, and is heavily ribbed; a flange extends around the entire shell.

"Bottom doors are of the hinged drop type, with preforated plate and four heavy ribs on each plate. On large cupolas there is provision for the attachment of levers for lifting the doors into place.

"The blast meter is of an improved water type, especially designed for this cupola.

"Improved tap spout, slag spout, and curved columns are supplied. The base plates of the columns are sufficiently large to properly distribute the load on the foundation, and are connected by means of tension bolts.

"A slag opening is located below the lower tuyeres, its height being adjustable to suit conditions. It is fitted with a suitable slag spout. By using the slag hole the cupola can be kept from clogging, and continuous melting for a long period will result.

"The charging door is extra large. The frame has a heavy iron slide at its base, protecting the lining.

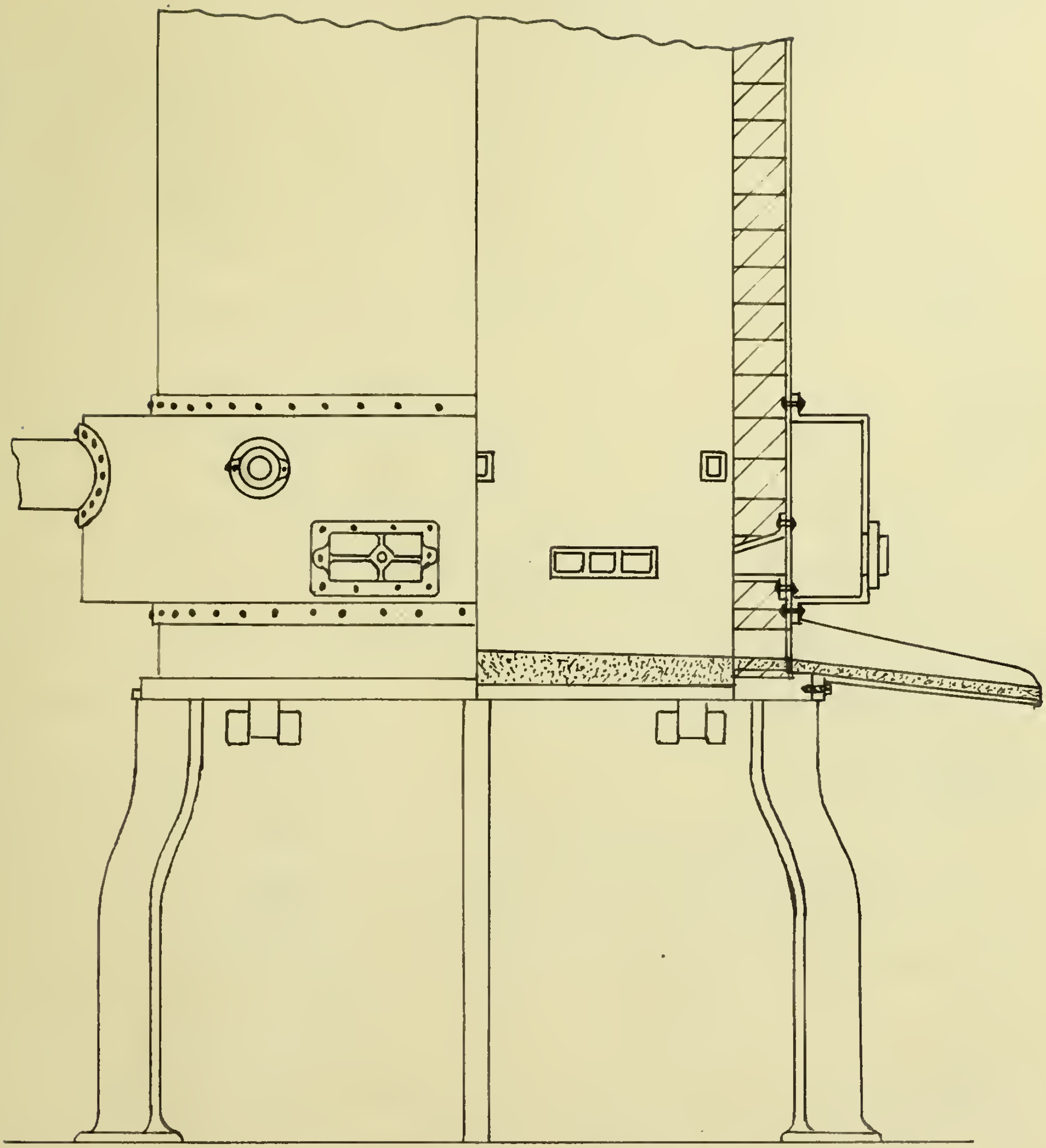

FIG. XIII

THE NEWTEN CUPOLA.

The charging doors may be either of the plate type for brick or mud lining, or of the wire screen type, the former being used unless otherwise ordered.

"The stack is of extra heavy steel, machine riveted in sections convenient for erection and having down opening joints. Sufficient bolts or rivets are furnished for connecting the various sections.

"Angle shelves are riveted to inside of shell at a suitable distance above the melting point, and also at frequent intervals throughout the stack for supporting the lining during repairs.

Fig. 14 is a section of this cupola through the lower tuyeres showing the expanded tuyere with the central portion contracted to send the blast into the cupola farther, the safety tuyere A, the entrance of the wind pipe into the air chamber B, and the tapping spout C. The following is what is said about the air chamber and tuyeres by the makers of the Newten cupola,-

"Special attention has been given to the methods of getting the blast to the fuel in the most direct and efficient manner.

"The entire body of the air chamber- bottom, top and sides - is made of plate steel, flanged riveted and caulked, insuring an air tight construction.

"BLAST INLET - The blast enters the chamber through a single inlet, which branches to right and left, giving a tangential motion to the blast in both directions.

"PEEP HOLES AND CLEANING DOORS - Large cleaning doors

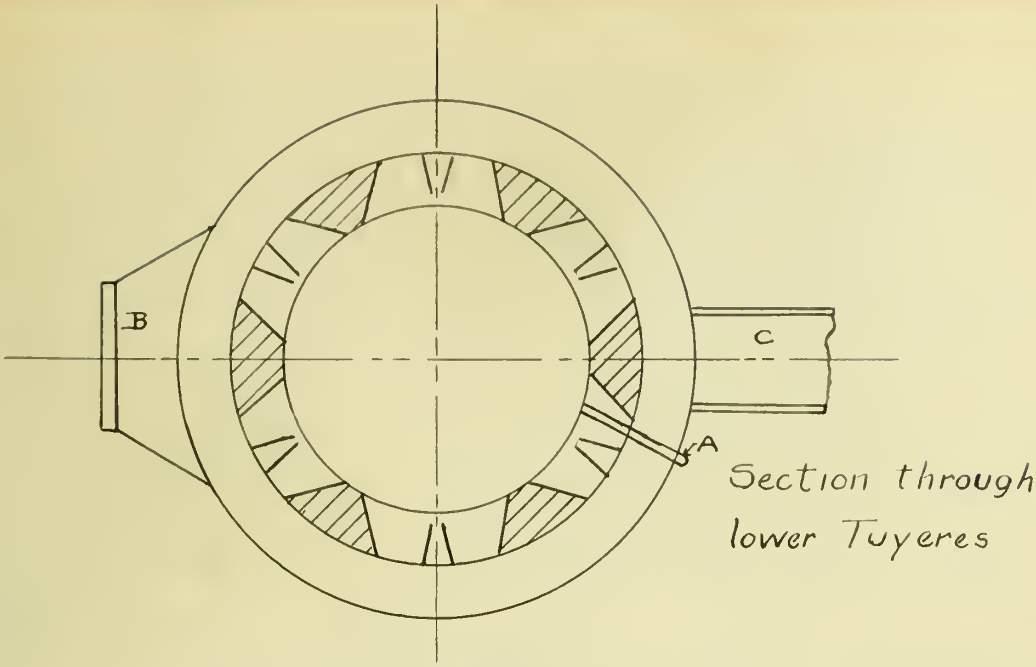

FIG. XIV

Air Chamber and Tuyeres of the Newten

with mica peep holes are located opposite each lower tuyere. As these openings are near the bottom of the air chamber, they afford ready access for cleaning.

"Peep holes with mica covers are also placed opposite each upper tuyere.

"Both cleaning doors and peep holes have planed and fitted joints, with adjustable fastenings. Care has been taken to make this air tight under the sever conditions of expansion and contraction experienced on cupola furnaces. A resulting economy of air results in a high melting speed.

"The bottom of the air chamber is raised several inches above the bottom plate; several inches of iron and slag cannot accumulate in this space as in the deep air chambers. There is open inspection of the bottom of the shell at all times, it being at this point that cu-

pola shells most frequently fail through rust.

"The patent differential tuyere system is in accord with the latest theories of modern cupola practice.

"The combined tuyere area is the important consideration, and the exact proportion which the areas of the tuyeres, blast pipe and air chamber bear to the size of the furnace and blower, has been carefully figured and adjusted to obtain the best melting speed and the most economical fuel results.

"The main tuyeres are of the expanded type, of ample area to insure the transmission of sufficient air to the furnace. The increase in the area of the greatest portion of the tuyeres as they approach the fuel gives a blast of large volume and of moderate pressure nearest the iron, and the wide tuyeres furnish nearly a continuous blast opening around the furnace walls. By these means ample blast area is assured even if part of the tuyere area is atopped by pieces of coke or other obstructions. Combined with this is the important feature of a differential blast.

"DIFFERENTIAL BLAST - The main tuyeres each have two supporting ribs, placed at an angle and giving a slightly contracted effect to a small portion of the blast, thus tending to force this portion toward the proportionately smaller area of the center of the cupola, while the expanding tuyere supplies the large area near the lining, resulting in a differential blast covering the entire area of the furnace. The result is a quick melt-

ing heat, and fluid metal with high fuel economy.

"ADJUSTABLE FEATURES - The lower tuyeres are adjustable vertically through several inches, to suit either a deep or shallow bed of fuel. This adapts the furnace to either coke or coal, or to any change of the inside diameter of the cupola,to suit all classes of work.

"SAFETY TUYERE - One tuyere has a low spout connected with a soft metal plug in the cleaning door, this is melted out and gives warning if the metal rises too high.

"UPPER TUYERES - On cupolas larger than 36" there are, in addition to the lower tuyeres, a number of upper tuyeres of much smaller area supplying air to assist in the combustion and utilization of escaping gases.

"TUYERE DAMPERS - The upper tuyeres are fitted with dampers enabling them to be closed if desired: the main tuyeres having ample area for the required capacity."

These are the leading American cupolas of today, each different in name and in some little detail and each claiming to be the best, yet,in general, all alike, and striving to the same end,- the most economical use of fuel to melt the most iron and with the least harm to the cupola-. All have the plain straight shell, the drop bottoms and the expanding tuyeres of large area in the lower row and an upper row of smaller ones.

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Chapter V

Running The Cupola

Every melter must run his cupola as best he can under the conditions that exist where he is; it would be easy to state just how a cupola ought to be run, but put that cupola into a foundry where all sorts of conditions are to be met, and the ideal must give way to the practical. On account of this, all that this chapter can do is to state certain principles or laws, governing the running of cupolas, which, in every day practice, ought to be lived up to as nearly as possible.

CHIPPING OUT the SLAG

When the cupola is cool enough to work in, or as soon as is necessary in order to get it ready for the next heat, the melter must go inside and with a short handled pick break or cut away the slag that adheres to the lining. When the slag has only formed a thin coat over the lining, it is better to leave it on, as it is very refractory and so forms a protective coat over the lining, while trying to get it off would probably injure the lining to a greater or less extent, thereby making it necessary to do more daubing. However, all knobs and projections must be broken off and all rough places smoothed down as they would tend to stop the stock from settling evenly, and so might cause the cupola to bridge or at least to dump poorly after the heat was over. Many foundrymen allow the slag to build out in knobs over the tuyeres with the idea that it is necessary in

order to keep the iron from running into them; however, these only make a good starting place for the cupola to bridge and when such projections and knobs are left on they become very hard so that they can hardly be removed. The picks for this work should be quite heavy and should be carefully sharpened before they are used, as it is of great importance that the slag be cut off with one clean blow rather than hammered and jarred until it is broken loose, in which case the lining is weakened by the hammering and probably will have to be repaired much sooner than if the melter had been furnished with a sharp heavy pick.

DAUBING and DAUBING MATERIAL

After the cupola has been well cleaned out with the pick it ought to be daubed, which consists of patching up the holes and rough places with a clay of some sort. The selection of the proper material for this daubing is important as it must be very adhesive,must be refractory, must not contract or expand to any extent upon being dried quickly, must not be of such a composition that it will melt and run off as slag when the blast is put on, and must be capable of being softened up in water so that it can be used to fill up the holes and cover over the cracks and rough places. If the daubing is such that it does not adhere well it will crack off when the blast goes on, due to the contraction and expansion, and is very apt to choke the furnace causing it to bridge and hang up the heat. If the daub-

ing is put on too wet it is apt to dry only on the outer surface, and then when the heat comes on, to glaze over, making the surface very hard before the rest is dried out; when this happens the rest of the moisture is turned to steam and escapes through the lining, if it can get out that way, or, if not, the daubing will be blown from the lining and choke the cupola. If the daubing is of such a composition that it melts during the heat it form a very tough slag that solidifies quickly and is very hard to remove from the walls of the cupola.

Moulding sand is often used for this purpose, but it is not very good as it fails to stick together when subjected to high temperatures and simply falls away from the lining it was to protect as a fine dust. Some clays make a good daubing just as they are found, but the best is made by mixing, in equal parts, fire clay and sharp sand. The clay and sand must be thoroughly mixed and the mixture put on the cupola walls just a stiff as it can be worked. This makes a very good daubing as it is adhesive, refractory and if mixed in the right proportions does not contract or expand as the heat comes on.

REPAIRING the LINING

Just above the tuyeres, where the heat is the most intense, the lining burns away the fastest, thereby enlarging the diameter of the cupola at that point. This is all right as long as the lining does not get too thin, so that the plates are heated, and as long as the increase in diameter is very gradual. If it is an abrupt

[illegible]

[illegible]

[illegible]

curve the stock does not expand to fill it in settling, so that much of the blast will escape along the wall, and when the stock has expanded a little, about the time it gets just above the tuyeres, the shelf formed gives it an excellent place to catch and hang either while in blast or after the bottom is dropped. Fig.XV shows a

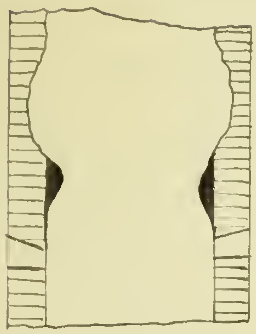

Fig. XV

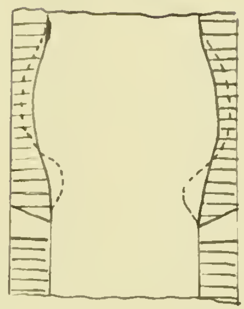

Fig. XVI

cupola where the lining has been allowed to burn away without being daubed up and Fig. XVI shows the same cupola with the lumps of slag cut away and the hollows filled up with fire clay and brick the way they should be to run a good heat. When the lining above the tuyeres becomes so thin that the daubing will not protect the shell it must be repaired with new fire brick or with broken fire brick and fire clay or daubing. Some foundrymen simply take out a few courses of the burned brick and replace them with new ones but these new brick project a little above the brick just above them, due to the lining being burned away more or less all the way to the charging door, and so are very easily broken when

charging the furnace. They are more easily gotten at by the heat also so that in a short time the cupola is in as bad a shape as it was before. Of course a new lining may be put in way to the charging door, but this is too expensive and besides it is not necessary as the lining above the melting zone will usually be all right for a long time after it is burned out lower down. The other way that a cupola in bad condition may be repaired is to put in enough stiff daubing to hold split bricks, pressed into it, to the wall,then, by laying up these pieces with the smooth side out and shaping them to fit the worn lining, the hollows may be filled, and still the bricks be kept from projecting beyond the lining above. This makes a good lining and can be used this way until the original lining becomes thin way to the charging door when, of course, a new lining must be put in.

THE CUPOLA BOTTOM

When the lining has been daubed in good shape then the bottom has to be made up. This is a particular job and should be done by a careful intelligent man who understands his work, for on the condition of the bottom, more than on anything else, depends the sucess or failure of the heat. If the bottom is too wet when made up, and is not in some way dried out before the iron comes down, the molten metal will boil on coming in contact with the wet sand, and by so doing work its way down through the sand to the bottom doors which are quickly melted. If not patched up in some way the whole heat will be lost

and the doors spoiled. If the sand of which the bottom is made is not wet enough it will not form a firm bottom, so that the melted iron quickly wears channels and hollows in it and so works through to the bottom doors with the same result as before. Not ramming hard enough has the same effect as having the sand too dry while too hard ramming will, unless the sand is very dry, cause boiling as does a wet bottom.

MATERIALS USED FOR THE BOTTOM

The sand used for the bottom must not be any of the clay sands as they all bake so hard that when the bottom doors are dropped the sand has to be broken out with an iron bar before the cupola will dump. Moulding sand that has been burned makes a good bottom when mixed with a little new sand; the amount of new sand depending upon how rotten the old is from repeated burnings. The sand that can be riddled out of the dump mixed with a little moulding sand from the floor makes a good bottom if it is well riddled and mixed. All the cinder, small pieces of iron or charcoal and such foreign matter must be carefully taken out as when melted they form a slag which which glazes over the bottom and makes it hard to drop. If the sand is well sifted and mixed with water to about the same consistency as moulding sand, a little drier if anything, it will form a good sound bottom which the iron will rest well on and that will drop readily when the bottom doors are dropped.

MAKING UP THE BOTTOM

The sand is gotten into the cupola the easiest way, usually through the front, which of course is open, and the moulder either gets inside the cupola, if it is a large one, or else reaches in through the front and levels the sand around: first packing it very carefully around the walls and the crack where the doors come together and then ramming it down firmly in layers an inch or so thick. The ramming should not be any harder than is used for an ordinary mould but it must be done evenly so as to leave a good surface. When the sand bottom has been built up to the right thickness, from three to six inches depending upon the size and length of the heat and the composition of the sand, the melter raises it a little around the cupola walls and sees that it does not meet the wall abruptly and so give the iron a chance to work down to the bottom doors. Then he levels the whole bottom carefully and sees that there are no soft places in it where the iron might form a hollow. The whole sand bottom is given a little slope toward the spout, from one-half inch to one inch to the foot is plenty, for if too great a slope is given, the iron will produce quite a pressure on the front and possibly break it out.

THE SPOUT LINING

Lining the spout is another job in which a good deal of care must be taken, and only the right material used, for if the iron boils and explodes when running down,

the men are in great danger of being burned if they try to catch the metal at all, and even if it does not fly it still may work through the sand and so burn out the spout. At many foundries the spout is made up new every heat or at least every few heats and although this is not nearly as important as the making up of the bottom or daubing the lining, still it is one of the important things that have to be looked after. Of course in many places the spout is lined with fire brick and only daubed over each heat but often this is not the case so it is well enough to say a few words about making it up right. In the old foundries the spout was formed by placing a couple of pieces of iron on the bottom plate on either side of the tap hole, and then filling in between them with moulding sand or clay. Now the spout is a part of the cupola, is made of steel or cast iron in the shape of a trough open at both ends, and riveted to the shell of the cupola.

MATERIALS FOR SPOUT LINING

Of course the best lining is fire brick grooved in the center and daubed before every heat as is the lining of the cupola. Many people do not use this but still make up a new lining every heat out of moulding sand or a mixture of fire clay and sharp sand; in some localities certain kinds of clay are used that make a good lining, but this is limited to the region where the clay can be obtained fairly cheap. All moulding sand will not do for spout lining but it is worth trying as it is so cheap.

Some of the sands are not refractory enough, but will fuse and melt when the iron runs over them, thereby making a slag that quickly clogs the spout. Others do not hold together well enough but will fall apart, when heated, so that the iron form little puddles and will not run out clean when the tap hole is stopped. The best lining, except of course fire brick, is the same that is used to daub the cupola, fire clay and sharp sand.

LINING THE SPOUT

About an inch of matterial is put in on the bottom of the spout and rammed down then the round stick is placed on it and the lining built up to the middle of the stick. From there it is sloped back to the sides of the spout. Where the lining meets the bottom of the cupola it is well to brush it over with a little clay wash to make it stronger.

THE FRONT OR BREAST

In comparison with the old style of cupolas the front that is put into a modern cupola is a small affair. Still if every thing is to go right during the heat, it must be carefully made. The following is taken from the Foundry,-

"To make a good breast, after the coke is well afire, insert fresh pieces of coke against the red-hot pieces in the cupola, making as smooth a wall as possible, and leaving a space of five or six inches form this coke wall to the outer face of the shell. This space may be varied according to the thickness of the lining; but for cupolas

of from 30 to 50 inches diameter, a tap hole six inches long will be satisfactory, under proper management.

"Having formed the bottom part of the breast level with the sand bottom of the cupola, and three-fourths of an inch higher than the center of the spout lining, take a mixture of one-half sharp sand and one-half fire clay, wetted to the right consistency, and wrap it around the smooth, slightly tapered iron bar with which you are to form the tap hole, and lay the forming bar thus surrounded into the groove scouped out of the middle of the floor of the breast; press it down till the bottom of the bar shall be three-fourths of an inch above the center of the spout, push it hard against the coke wall, throw in new moulding sand and ram it hard. Take a moulder's tool and form the front straight up and down. Withdraw the forming bar, and leave the edge of the tap hole flush with the front of the breast. Black-wash with plumbago in water. The black-washing is important. True, there are many foundries where it is not practiced; and they get along tolerably well with out it; some of them very well indeed. But the spatterings of the molten iron cling with great tenacity to the bare fire clay and moulding sand breast, making it difficult to keep it clean and intact. The breast ought to be in as good a condition at tne end of a heat as at the start and the black-wash is a great help to that end. With it, the iron can readily be removed from about the tap hole without crumbling or chipping away any of the sand from the

[illegible]

breast at the first few taps, and by that time the sand around the tap hole will have become baked so hard that there will be no danger of damage from reasonable careful use of the tapping bar.

"I have indicated that the bottom of the tap hole should be three-fourths of an inch above the bottom of the spout. This is another of the unnecessary things, a feature in fact that the majority of melters get along without- just as the majority of melters used to get along without weighing or measuring the stock.

"A little reflection will show that a tap hole thus constructed can be more easily and securely stopped than when it is on a level with the bottom of the spout. In the latter case, if as too often happens, an obstruction becomes built up in the spout near the tap hole, it is almonst impossible to stop perfectly, and, under these circumstances, the trouble grows as the heat advances. And the difficulty is aggravated when the effort to clear away the obstruction results in opening up the tap hole before the work is done, and the up-shot of it is that the melter has to stop up as best he can by raising his hands as high as possible and trying to force the bod hard down at the bottom of the tap hole, but meeting with poor success, for the iron will somehow find its way out in greater or less quantity.

"Another point in connection with the cupola breast is to let the sides and bottom of the spout, at the breast, be lined with fire bricks. In my own practice the whole

of the spout is thus lined. But it is especially important at and near the tap hole, because it is sometimes necessary to use a good deal of force in chipping away the obstructive substances that accumulates there, and a less firm lining of the spout would be liable to yield to this hard usage, and so cause trouble and possibly disaster.

"I said above, keep the edge of the tap hole flush with the front of the breast. Some melters ream out the front of a tap hole as a moulder reams out the top of a pouring gate. In the latter case, the stopper wedges in so hard that it is difficult of removal, it cannot be kept clean, and in tapping out, the shape becomes distorted and a great deal of unnecessary trouble ensues.

"Where the tap hole is left flush with the front, a very little agitation with the bar will enable the molten iron to force away the stopper, and the breast and tap-hole will remain intact."

The size of the tap hole depends upon whether it is desired to run a continuous stream of iron or to hold the iron in the cupola and then draw off a good deal at one time. When the first method of drawing off is necessary, a very refractory material must be used around the hole so that it will not become cut up by the iron and so grow larger as the heat progresses. When the other method is used a larger hole must be provided so that the iron can flow out faster and so not have time to cool. However a poorer material may be used around the hole as it does

not have to be tapped out so often and even if it does become a little larger it does not make much difference.

MAKING THE BED, LIGHTING AND CHARGING

When it is time to get the cupola ready for lighting, the melter, if the cupola is large enough, goes (~~down~~) down into it and has the shavings, or straw, if it is easier to procure, and wood passed down to him by a helper. The shavings, or straw, are spread over the bottom evenly and then small sticks of wood are laid on in such a way that they will burn up quickly and evenly. On top of these a few pieces of heavier wood are placed. Then the melter gets out and throws in enough wood to light the coke which is then put in. All the wood used must be in small pieces of pine or some other light wood that will burn up quickly; if large pieces are used or if a hard wood is used, smoke will continue to be given off even after the bed is well afire thereby making it very hard to charge the fuel and iron evenly. Of course if the cupola is a small one everything must be thrown in from the charging door and left as it may fall except for the little arranging that the melter may be able to do by reaching in through the front. Enough coke or coal should be put in so that the top of the bed will be at the melting point of the cupola after it is all well afire. Mr. Kirk * says that the rule is as follows,-

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* From "The Cupola Furnace" by Kirk

"If coal is used put in enough to bring the bed 14 inches above the tuyeres; with hard Connellsville coke enough should be put in to bring the bed 18 inches above the tuyeres and with soft coke enough to bring it from 20 to 25 inches above. He also says that this rule will not always hold and gives the following method of finding the melting point so that the right amount of fuel may be used.

*"To find the melting point a bed is put in according to the rule and iron charged upon it. If the iron is a long time in coming down after the blast is put on, or if the iron melts slowly during the melting of the first charge, but melts faster at the latter end of the charge and is hot, the bed is too high and the iron is being melted on the upper edge of the melting zone. Fuel and time are then being wasted, and the fuel should be reduced so as to put the iron at the melting point when the melting begins. If the iron comes down quickly but is dull, or if it comes down slow and dull and does not grow hotter at the latter end of the charge, the melting is being done on the lower edge of the melting zone and the quantity of fuel should be increased to bring the top of the bed to the melting point. When the top of the bed is only half way up to the melting point, the iron comes down hot and fast, but the bed does not melt the quantity of iron that it should and the latter part

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* From "The Cupola Furnace" by Kirk, page 93

of the charge on the bed is dull. The latter part of the charge on the bed is dull, when the bed is the proper height, if the charge is too heavy for the bed, and care must be taken in noting this point.

"If by comparison with charges of iron in various sized cupolas the charge on the bed is found to be light, the bed should be raised until the melting indicates that it is at the proper height; then the weight of iron on the bed may be increased, if the charge is too light. When raising or lowering a bed, it should be done gradually by increaseing or decreasing the fuel 50 to 100 pounds each heat until the exact amount of fuel for the bed is found."

Usually the front is left open so that the shavings may be lighted and also to furnish a draft for the burning of the wood. The tuyeres are always opened too so that there is quite a draft up the stack and the bed ought to burn up quickly and evenly. If it burns up only on one side there is not much use of continuing the heat, unless in a large furnace, as the fire will very seldom spread to the whole area of the cupola if it is not started there. When the fire is burning well the melter builds up the breast, as described above, and then usually builds a wood fire on the spout so as to dry the spout lining and the breast as much as possible before the iron begin to come. As soon as the smoke has burned off so that the melter can see the bed he

puts in a few shovels full of coke to level it up and then begins to charge the iron. In charging the iron and fuel are not mixed up but are put into the cupola in charges. Care must be taken not to make the charges too large, as, if they are, fuel will be wasted and still the iron at the end of each heat will come down dull. The charge of iron must be just enough so that when it has settled to the lower edge of the melting zone it will all be melted and the succeeding layer of fuel should then just bring the bed up to the melting point again. When the cupola is first charged it is filled up to the charging door with these succeeding layers of iron and fuel and then, as these settle down, more are put on until all the iron to be melted has been charged. Then the stock is allowed to settle and the iron is all drawn off before the bottom is dropped.

Care must be taken in charging to get the iron in the cupola or the different grades may not mix as they should. When charging a good deal of pig and only a little scrap the pig should be broken and charged first, care being taken to try and get them in so that they will with their ends toward the lining as otherwise they are protected a good deal by the lining and do not melt so quickly. The scrap should be spread on top of them in such a way as to fill up the spaces between the pigs and make a better surface to put the succeeding charge of fuel on. If a good deal of scrap is used with the pig the latter must be broken up into smaller pieces, say each pig in-

to four or five lengths, so that the heat will have more chance at it,- melting goes on at the ends of the pigs, so the smaller they are broken, the faster they will melt, as that much more surface is exposed,- and charged first as before, with the scrap on top. By charging the iron this way, the scrap, protected as it is by the sand on it, will melt about as fast as the heavier pig so both will come down together thereby insuring a good mixing. When more than one kind, or grade, of pig is to be used in a heat it must be well mixed before charging so that all the pieces of one grade will not get thrown in together and so not mix well with the other grades. Of course if it is a large cupola and the charges are very heavy it may be necessary to make each charge into two or more layers, first a little pig then some scrap and then somemore pig and scrap, so as to get them well mixed.

FLUXING AND FLUXING MATERIALS

If it is desired to run a long heat, then it is neccessary to use some kind of a flux and to draw off the slag either continuously or at intervals. The best fluxing material is some form of carbonate of lime, usually lime stone, marble chips (which are about the best) or oyster shells, and is either put in after the cupola has been entirely charged, or a little is put in with each charge to absorb the sand and ashes and also the impurities from the iron. Some melters do not put in enough to produce a slag that can be drawn off but only enough to make the slag, that will always remain in the cupola

after the bottom is dropped, more brittle and therefore easier to get out. The quantity of flux necessary depends entirely upon the condition of the iron that is to be melted, and the fuel that is used. The ordinary amount of flux used with one ton of iron melted varies from 25 to 100 pounds. If the gates and sprues are covered with a good deal of dirt and sand, or if the fuel that is used burns with a good deal of ash, then a good deal of fluxing material should be used to take care of all this refuse. If, on the other hand, the iron is quite clean and the fuel does not leave much of any ash, very little, if any, of the flux is necessary in a short heat. Of course in a long heat the flux must be used even if the iron is clean as there will be more or less refuse and impurities to be taken care of.

THE SLAG HOLE

The slag hole is placed just below the tuyeres on the side opposite the tapping spout and is usually furnished with a short spout which has to be lined as does the tapping spout. The lining is cut away a little at the slag hole so as not to leave so long a passage in which the slag may cool and so stop the flow. If it is desired to run the slag off only intermittently, a fairly large hole is necessary, and it has to be stopped up and tapped out as does the tap hole.

THE BLAST

As soon as the cupola is all charged and the bed is

burning well the tuyeres are shut, that is, the shutters in the outside casing which have been open up to this time to give a draft are shut, and the blast is put on. It is usually an hour and a half to two hours after the fire is lighted before the blast is put on. However, after the blast does go on, if everything is all right, the iron ought to begin to come in from fifteen to twenty minutes. The first that comes is usually allowed to run out, and is used to dry the spout lining and the ladles, as it is too dull to be used in the moulds. Then the cupola is stopped in, if the iron is to be allowed to gather in it, or it is left open so that a continuous stream flows from the cupola and the moulders begin to pout the moulds with hand ladles.

THE BOD and "STOPPING IN"

"Stopping in" a cupola, as it is called, is a job the knack of which is very hard for some people to obtain and in fact many are not able to do it well even after many years of experience. First let us consider the material that is used for stopping in. This may be simply moulding sand that is mixed up a little wetter than it would be used for moulds, or if the moulding sand does not make a good "bod", as the little plug of sand that is used to stop the hole is called, it has to be mixed with other materials to make it more adhesive: these may be either blue or yellow clay, or if they cannot easily be obtained, a very little fire clay may be

used, but only a little, as if too much is put in, the bod will bake so hard that it will be next to impossible to cut it out without spoiling the front. When the material for the bods has been prepared, it is shaped, by hand, into little cones, somewhat larger than the tapping hole, and these are then placed on the ends of the bod sticks. The bod stick is a round rod made either entirely of wood or else of a iron rod having one end enlarged and a wooden handle on the other. The end upon which the bod is placed must be from one and one-half to two inches in diameter while the rod is anywhere from four to ten feet long.* They are made with an iron end so as to avoid burning them every time that the tap hole is stopped but at the same time the iron ones are open to the objection that they have to be cooled off in water after each using, in order not to dry out the bod before it is used, and so rust, which is apt to cause the iron to fly when they are used. The bods are usually formed right on the bod sticks, although some melters will make up several, place them where they will not dry out and so have them ready to put right on the stick. The bods are of different size and shapes, depending upon how the iron is to be tapped. If it is to be tapped often, and only a very little allowed to collect in the cupola, a small shallow bod is used so that it may be easily broken out at the least touch of the tapping bar;

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* From "The Cupola Furnace" by Kirk, page 110

If it is to stay in a long time, and a good deal of iron is expected to gather in the cupola, a long pointed bod is fashioned so that it may be pushed well into the hole and so stop it up good and solid. Of course these are hard to remove but they have to be used in order to keep the mass of molten metal from forcing them out before the time comes.

The hardest job is to put the bod in, as it must be done quickly and surely, and must cut the flow of iron off sharply, if it is to be done without making the sparks fly. The rod should be held at a sharp angle with the spout, the bod just above the stream of iron and squarely in line with the hole, and then it should be pushed quickly and surely down into the hole and the bod stick held against it for a minute to insure its setting well; then the stick may be removed and gotten ready for the next stopping in. If the spout is too high to be reached easily a platform ought to be built, or at least something solid provided to stand on, so that the melter can get the required angle when stopping in.

TAPPING and TAPPING BARS

The bars the tapping is done with are from four to ten feet long and from half an inch to one inch in diameter* and are made of steel or iron. There is usually an oval ring formed on one end for a handle while the

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* From "The Cupola Furnace" by Kirk, page 109

other is pointed and sharpened to cut out the bod. The may be shaped to suit the fancy of the melter but are usually round or square. A rod having a square point makes a very good hole and when rotated a little in the hole cleans it out nicely but, after a tap or two, the corners are melted off by coming in contact with the hot metal and the point becomes round. Some melters have a short rod, with a flat sharpened point, that they use to cut away most of the bod but this is never used to break way through as the molten iron would quickly spoil the point on the rod. In cutting the bod out the point of the tapping bar is placed against it and then pushed in while a circular motion is given to the handle. As soon as the hole is through, the bar should be run a little way into it a couple of times to clean it out in good shape, but it must be kept perfectly true with the spout or the iron may fly over the sides when it comes out.

DUMPING

As soon as the last of the moulds are poured the melter has to think about getting ready to dump the cupola. The blast is shut off and all the tuyere gates opened so that no gas will get into the blast pipe where it might cause an explosion the next time the blast was put on. All the melted iron in the cupola is drawn off and poured into pigs and if there is still any unmelted iron in the cupola it is given time to melt and run down, however, if the unmelted iron is in the shape of pigs the bottom is dropped at once as the pigs can easily be picked out

of the dump. If there is more than one prop under the bottom the smaller ones are taken out, and then the main one is either pulled out with a long hook or else knocked out with a long bar. When the doors fall most of the ash and refuse will fall to the floor but often only a part of the bottom sand will fall until after the melter has started it with a long bar and even then the bottom may be the only thing to fall. When this happens the only thing to do is to try and poke the rest loose from the tuyeres, or, if this cannot be done, to break it down from above by dropping heavy pieces of iron into the cupola. As soon as the refuse has dropped, water is thrown on it and then it is raked out and the large pieces of iron picked out by hand, or it may be put into a tumbling barrel where the iron soon separates from the rest. In this condition the cupola is left to cool off so that by morning it will be cool enough to be chipped out and gotten ready for the next heat.

Chapter VI

Conclusion

The FOUNDRY at the UNIVERSITY of ILLINOIS

The foundry connected with the University of Illinois is located in the rear of the Wood Shop and is under the same roof. It is 80' x 36' inside with large windows on three sides which give ample light and air. The main floor of the foundry is made of reenforced concrete on which a floor of cedar blocks is laid and covered with moulding sand.

Under the foundry proper is a good light basement in one end of which are kept the foundry supplies, new moulding sand, coke, iron, flasks etc. In the other end is located the fan, rattler and elevator drive. The fan is a Buffalo Forge Co. 35" fan blower connected by belts to a Westinghouse 10 H.P. motor which also furnishes the power for the rattler and elevator.

The cupola is a Whiting No.1 and has been in use here several years. The cupola has given excellent service, and when large castings were to be made has been run at several times its rated capacity. The cupola is located in a small bay midway along one side of the foundry. In this bay is also located the elevator and the stairways to the charging floor and basement. The second floor of the bay form the charging floor thereby leaving the whole of the foundry clear with the exception of one end where there is a bench for core making and a small core oven.

The foundry is provided with a Whiting, 5-ton hand-power traveling crane. Running out through large double doors at one end of the foundry is a block and tackle arranged to run on an overhead track so that heavy pieces may be moved outside without any hand work. The general arrangement of the foundry is shown in the elevation Fig. XVIII and the plan Fig. XVII.

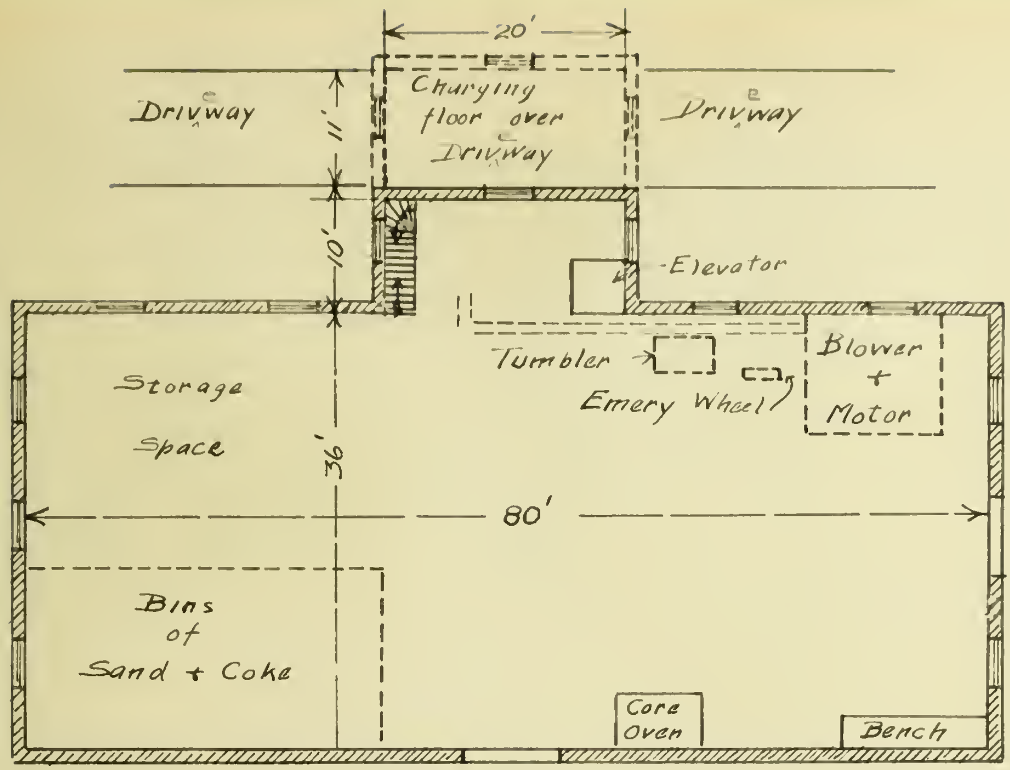
The MEASUREMENT of the TEMPERATURE of MOLTEN IRON

The following is a short description of the methods used and the results obtained in finding the temperature of molten iron.

THE THERMO COUPLE METHOD

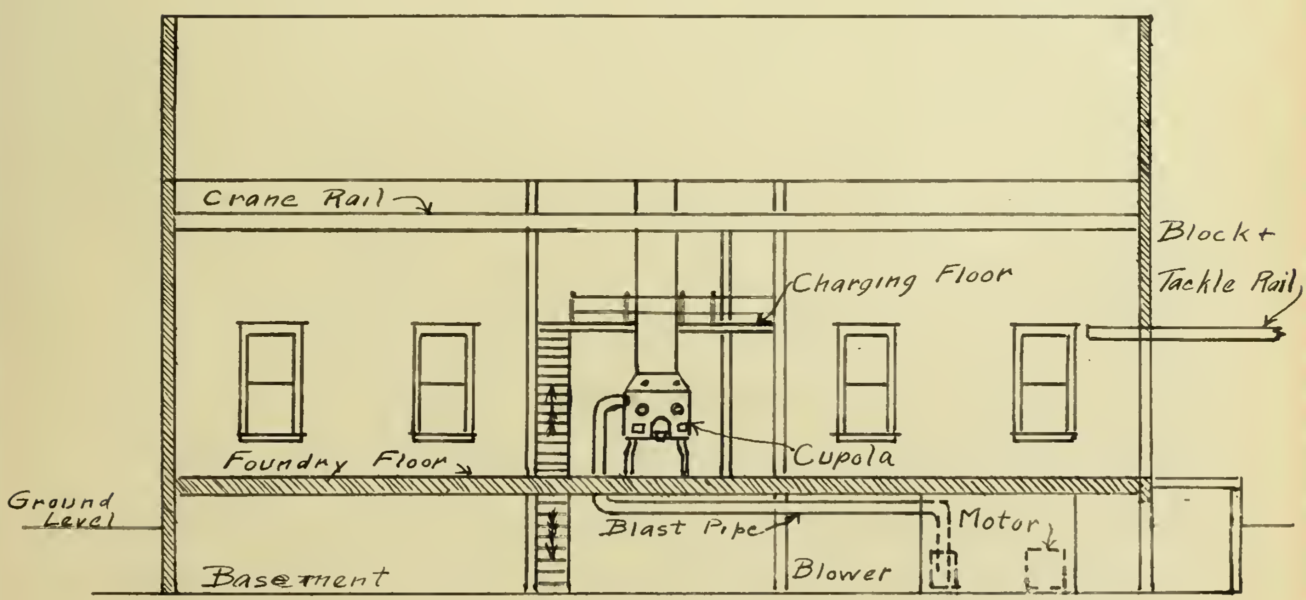
This method of determining temperatures is based on the fact that two unlike metals placed in contact and heated will give an electric current. This small current is used to move a pointer upon a graduated scale that reads in degrees of heat. In these experiments a platinum wire was run through a long pipe clay tube while a platinum-rhodium wire was run down outside the tube. At the end they were joined so that they could be put into the melted iron. The two other ends were attached to the poles of a galvanometer graduated to read directly in degrees.

Good results were obtained with this apparatus at first but when iron and copper wire was used it melted so fast that no reading could be taken.



PLAN
Fig. XVII

UNIVERSITY of ILLINOIS FOUNDRY



ELEVATION
Fig. XVIII

THE CALORIMETER METHOD

The theory of this method of determining temperatures is that heat will flow from a body of higher temperature to one of lower temperature until the two bodies are of equal temperature, when the flow will stop.

For a calorimeter we had a small brass can that would hold about a gallon of water. Inside of this was another can, also of brass but a couple of inches smaller in diameter and not quite so deep. The space between the two was filled with asbestos and over the top was placed a thick wooden cover, with a small opening in its center so that the iron could be poured in and the thermometer put in to read temperatures. Inside the smaller can there was a small brass tray, raised from the bottom a little to receive the molten iron so that it would not melt through the bottom of the can.

The weight of the inner brass can was first measured, then the can was filled nearly full of water and the weight of water added determined. The iron was then poured in and the rise in temperature taken. When it had become normal the mixture was again weighed to obtain the weight of iron added. Knowing the rise in temperature of the water and the brass, their specific heats and the specific heat of the molten iron, also the weights of each, it was an easy matter to find the fall in temperature of the iron by use of the following relation: the rise in temperature of the water times its weight,

times its specific heat, plus the rise in temperature of the brass, times its weight. times its specific heat, is equal to the fall of temperature of the iron, times its weight, times its specific heat; all of these factors but one, the fall of temperature of the iron, are known so that one may be easily found.

After using about half a pound of iron to about four pounds of water, we obtained quite good results; but with more iron the water boiled and was thrown out at the top of the can. The results are shown below tabulated with the results of the other two methods.

THE OPTICAL PYROMETER METHOD

In this instrument the intensity of the red rays of light from the source of heat are compared with the intensity of the red rays from a standard light held in the instrument. Then from the laws connecting the intensity and temperature of light the temperature of the source was found. The light enters through an adjustable slit in one end of the instrument and is thrown on a reflector where it is seen beside the image of the standard light. These two images are brought to the same intensity by opening or closing the slit through which the light enters. Several good results were obtained by this method but they run higher than those obtained by the calorimeter or by the thermo-couple.

Table of Temperatures

Date	Thermo Couple	Calo-rimeter	Optical Pyrometer
Mar. 31	1140		
" "	1135		
" "	1210		1232
" "	1410		
" "	1140		
" "	1120		
Apr. 6		1095	1135
" "			1135
Apr. 13		1470	1635
" "			1615
" "			1615
" "			1615
" "			1615
" "			1465
" "		1220	1430